4/p.

N 62 13774

NASA TN D-1274

NASA TN D-1274

CASE FILE COPY

TECHNICAL NOTE

D-1274

CAPE CANAVERAL WIND AND SHEAR DATA (1 THROUGH 80 KM) FOR USE IN VEHICLE DESIGN AND PERFORMANCE STUDIES

By James R. Scoggins and William W. Vaughan

George C. Marshall Space Flight Center
Huntsville, Alabama

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON July 1962

NATIONAL AERONAUTICS AND SPACE ADMINSTRATION

TECHNICAL NOTE D-1274

CAPE CANAVERAL WIND AND SHEAR DATA (1 THRU 80 KM) FOR USE IN VEHICLE DESIGN AND PERFORMANCE STUDIES

by

James R. Scoggins

and

William W. Vaughan

SUMMARY

This report provides a review of the concept of wind shear and provides information relative to the various types of shears and their relationship for describing the wind environment. The use of these shear descriptions is described in terms of the vehicle flight attitude by resolving the shears as defined in an earth-fixed coordinate system into a vehicle-fixed coordinate system. A preliminary estimate is given for the magnitudes of perpendicular and horizontal wind shears as functions of the established vertical wind shears.

In addition, a consolidated presentation is given of standardized wind profile envelopes for the 95 and 99 percent probability levels, and related 99 percent envelopes of vertical wind shear and wind speed change spectrums for use in constructing synthetic statistical wind buildup profiles for Cape Canaveral, Florida (Atlantic Missile Range).

SECTION I. INTRODUCTION

During the recent years, there has been a large amount of material presented regarding the wind environment as related to airplane performances. The information gathered was in regard to wind conditions affecting horizontally flying aircraft. Unfortunately, this does not provide an adequate representation of the conditions affecting vertically rising vehicles (missiles and space vehicles).

One of the first groups to publish a paper pertaining to wind conditions which might be encountered by a vertically rising vehicle was the Air Force Cambridge Research Center (Ref. 1). This document and subsequent additions (Ref. 2 and 3) have become the foundation for establishing synthetic statistical wind profiles, etc., for use in various missile structural and control system design studies. In 1958, a report was published by Langley Research Center (Ref. 4) which provided an analysis of airplane wind measurements with reference to missile operations. The conclusions of this analysis were that the airplane data are applicable to missile flights with near-horizontal flight paths, but are not applicable for near vertical flight paths through the atmosphere. Most larger missiles and space vehicles maintain a near vertical flight path throughout most of the earth's atmosphere in order to attain an early condition of minimum drag and, therefore, maximum efficiency from the vehicle's thrust for payload and mission performances.

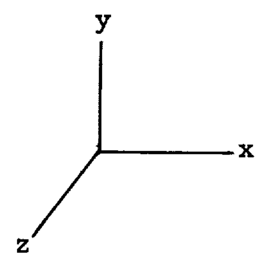
The usefulness of a true representation of atmospheric data in missile and space vehicle design studies is largely dependent upon the analytical procedures employed in structural and control studies. To date there have been two major methods employed: (1) Synthetic wind profiles, and (2) Stationary and nonstationary statistical techniques. A study by WADC (Ref. 5) provides a brief discussion of these methods. The first method is very useful because of the relative simplicity of introducing synthetic wind profiles in vehicle structural and control studies. The second method employs rather complex statistical representations of the atmosphere. Studies are being made (Ref. 6, 7, and 8) which attempt to arrive at a suitable statistical approach for defining the detailed vertical wind conditions and incorporate them into a realistic analytical expression for missile and space vehicle system responses.

This report further refines and amplifies the information presented in references 1, 2, 3, and 14 for wind shear and wind speed change as a function of scale-of-distance for the altitude levels from 1 to 80 km for Cape Canaveral, Florida. The objective is to expand on the synthetic profile concept with the idea of presenting a more detailed description of wind magnitude and wind shear relative to vertically rising missiles. It is also hoped that design personnel engaged in employing atmospheric data will better understand the complexities involved in establishing analytical descriptions of the wind characteristics and the physical interpretations as inputs into their studies.

SECTION II. DEFINITIONS OF PARAMETERS

The following definitions will be used throughout this report:

<u>Coordinate System</u> - The coordinate system used is earth fixed and is represented as follows:



Where: The x-axis is oriented east-west, positive east;
The z-axis is oriented south-north, positive south;
The y-axis is perpendicular to the xz-plane, positive upwards;
The xz-plane is tangent to the earth's surface.

Wind Velocity - The vector representation of the three-dimensional (x, y, z) wind flow.

Wind Shear - The variation of the vector wind field along a given direction (directional derivative).

Horizontal Wind Velocity (W) - The component of the wind velocity vector that is in the xz-plane.

Vertical Wind Velocity (V) - The component of the velocity vector that is perpendicular to the xz-plane (parallel to the y-axis).

Vertical Wind Shear - The derivative of the horizontal wind velocity, W, with respect to the y-axis (altitude), $\partial W/\partial y$.

Horizontal Wind Shear - The derivative of the horizontal wind velocity, W, with respect to an axis, s, parallel to the earth's surface and in the xz-plane, $\partial W/\partial s$.

Perpendicular Wind Shear - The derivative of the vertical wind velocity, V, with respect to an axis, s, parallel to the earth's surface and in the xz-plane, $\partial V/\partial s$.

SECTION III. FUNDAMENTAL CONCEPTS REGARDING WIND SHEAR CHARACTERISTICS

In order to describe the discrete wind magnitudes and associated wind shears for which a vehicle should be designed to insure given operational capabilities, it is necessary to establish certain ground rules regarding interpretation of data, both input and output. Furthermore, the results obtained from using the data presented, in terms of structural or control requirements, depend to a certain extent upon the philosophy employed in the dynamic studies. Therefore, a critical interpretation of the wind input used must be made in terms of the study objectives and analytical procedures employed to compute structural and control responese.

The wind patterns which exist aloft are a complex and variable physical event. Although the basic flow patterns are governed by thermal and pressure relationships in the larger scale, there is a multitude of combinations for wind velocities versus altitude possible at any particular time and location. It is well known that a westerly jetstream wind maximum exists over Cape Canaveral, Florida, near 12 km altitude during the winter months which diminishes during the summer months. Also, the higher altitude (>50 km) westerly maximum wind in the winter reverses to an easterly flow in the summer and has about twice the magnitude of the 12 km wind maximum. However, within these general, broad, and more pronounced features, there are numerous combinations of wind patterns which may occur.

The correlation coefficient for wind velocities between various altitude layers is generally not large except for layers up to 4 or 5 km (Ref.9). A typical interlevel correlation of wind velocities will show a correlation coefficient of 0.5 or greater between winds within layers of about 4 to 5 km thickness depending on altitude, seasons, etc. Therefore, the realistic representation of a discrete wind profile in a given probability level is dependent upon the altitude level used to establish the wind profile.

A wind profile, as traversed by a missile or space vehicle, is characterized by two rather distinct parts: (1) the wind magnitude and (2) the wind shear. Both are important in determining control system requirements as well as structural loading conditions. Measurements of wind velocity have shown the interdependence of shear values to be such that the largest wind shears to be expected are associated with the smallest altitude layers (scale-of-distance). Therefore, as one step toward improving representation of wind shears, a varying wind shear must be employed which is dependent upon the altitude layer(s) under consideration.

In accordance with the above, a philosophy will be developed relative to expressing the discrete wind profile and wind shear data for space vehicle design studies. First, based on the vehicle system objectives, an acceptable statistical design probability level must be selected which represents the percentage of acceptable operational capability desired for a given reference period and location. After this determination, a standardized wind magnitude profile may be established which provides an envelope of the wind magnitudes as a function of altitude not expected to be exceeded for the given probability level. Two such profiles are given in this report for a vehicle design based on a 95 percent and a 99 percent probability level design philosophy for a monthly reference period. This then produces a risk level, not in terms of loss of the vehicle during flight for a space flight test vehicle, but in terms of possible test schedule delay due to observed winds in excess of the design value, provided the control system and structural design have been developed to withstand only these wind conditions. Interpretation of the effect of a given wind criterion on a particular vehicle system depends upon mission objectives, specific vehicle design limitations, etc., and is a rather complex problem.

The ultimate goal for wind studies is to establish an adequate statistical relationship between the occurrences of wind speeds and shears so that a realistic physical representation results which can be utilized in a practical method in control system and structural studies for space vehicle design. Unfortunately, there does not exist an acceptable statistical model for prediction of control requirements and structural loads which incorporates the dynamic characteristics or representation of the detailed physical features of atmospheric dynamics as an input. Therefore, the techniques of expressing the physical features of the wind structure in terms of various discrete (synthetic) profile methods still have considerable value. This is especially true because of the rather wide usage and relative simplicity in description of this method for describing the wind and wind shear values as inputs to quasi-steady state and dynamic response studies to establish over-all design limitations.

The basic wind measurements will be considered exact for purposes of this discussion and the problems associated with how the wind velocity was measured and assessed at a particular altitude will not become involved at this point. In the final analysis, this is an important point to consider, due to the dependence of shear on the Δs and Δy terms. Since the wind shear is determined over a given layer, the shear is assumed linear based on the method of computation, i.e., ratio of velocity and distance (altitude) differences. The interrelationship between various wind shears and their probabilities of a simultaneous occurrence in a given profile have not been determined. Therefore, a series of shear computations are made for varying distance (altitude) layers, i.e., scale-of-distances, and the results provided in terms of an envelope about the shears which could be expected to exist at a given altitude level. With the wind magnitude envelope, this approach provides material for construction of discrete (synthetic) wind profiles which will include the rate of wind buildup over a range of scale-of-distances (or for select scale-of-distance) leading into the wind magnitude at any given altitude. This method for constructing design wind profiles is somewhat conservative from both the statistical and physical viewpoints. However, the evolution of more accurate descriptions for the wind conditions will be a slow and difficult process in order to insure an understanding of the physical mechanism and an accurate analytical description thereof. This is true whether made graphically or mathematically from complex statistical and dynamic models. Furthermore, the process of describing the wind conditions as given herein is considerably more representative of the actual wind dynamics than that obtained by using one value for shear, shear layer, and wind magnitude for large altitude ranges in missile or space vehicle design studies.

It should be emphasized that in order for the wind velocity profile to produce a given shear over a certain altitude layer (scale-of-distance), there exist numerous combinations of wind shear for the smaller scale-of-distances which are contained in the larger defined scale-of-distance (altitude layer). Adequate data do not exist to establish analytical methods for describing the interrelationship of the various shears. Therefore, the use of an envelope which presupposes a positive correlation between the wind shears for the different scale-of-distance insures a safe representation of the wind build-up rate for use in structural and control system design studies.

SECTION IV. INTEGRATED WIND AND WIND SHEAR PROFILES ESTABLISHED AS VEHICLE DESIGN CRITERIA FOR CAPE CANAVERAL, FLORIDA

A. SOURCE OF DATA

The data used to expand the vertical wind shear representations as a function of altitude were obtained from two major sources: (1) balloon measurements, and (2) rocketsonde measurements at Cape Canaveral, Florida. This provided relatively adequate data to establish shear values for scale-of-distances from about 500 m to 5000 m in the altitude range from surface to 70 km. Above 70 km, data were obtained from sodium trail measurements, all of which were made at other locations. Establishment of shear values for scale-of-distances below 500 m was done by using estimates based on MSFC missile measured (angle-of-attack) winds, aircraft accelerations, smoke trails, and theoretical models.

B. PRESENTATION OF DATA

The approach outlined under Section III is the basis for the following discussions of wind and wind shear. Because of the highly irregular behavior of the wind, it is impossible to express the variations of wind and wind shear as a function of altitude in a simple manner. For this reason, the profiles have been idealized.

Although all available sources of data were utilized, it must be realized that the information presented herein is still somewhat speculative. There does not exist any published material which has analyzed and presented these data in this form. The nearest approach has been to describe the probabilities of occurrence for various airplane gust magnitudes as a function of altitude. These descriptions have encompassed the region from near the earth's surface to about 25 km altitude. However, they do not give any information on the relationship of gust magnitudes to scale-of-distance or to associated vertical wind profiles.

1. Ninety-Five Percent Probability Level Wind Profile Envelope. The profile given in FIGURE 1 provides an envelope about the wind speeds which are not exceeded on an average of 95 percent of the time during the windiest monthly period at Cape Canaveral, Florida. The windiest monthly period is defined as the monthly period having the maximum average wind speed in the 10 to 14 km altitude region. This is the altitude region of maximum dynamic pressure, which is of considerable importance in establishing vehicle control and structural requirements, for most missile and space vehicles.

The bar graph included in FIGURE 1 shows the percentage of the time that the 75 m/sec wind speed is exceeded in the 10 to 14 km altitude region. It can be seen that March has the strongest winds at these altitudes with 5 percent of the observed winds exceeding 75 m/sec. The percentage of winds which exceed 75 m/sec varies throughout the year with July, August, and September wind speeds not exceeding 75 m/sec.

2. Vertical Wind Shear Spectrums Associated with the 95 Percent Probability Wind Profile Envelope. FIGURE 2 shows vertical wind shear (vector difference in the horizontal wind velocity at different altitudes divided by the difference in altitude) as a function of altitude from 1 km to 80 km associated with differentials in altitude (scale-of-distance) from 100 m to 5000 m. These shears were derived for association with the wind speed profile envelope given in FIGURE 1. They represent shears which are not expected to be exceeded 99 percent of the time, provided the wind speeds given by the wind profile envelope are not exceeded. Efforts were made to establish the shear values in the 20 to 35 km altitude region such that negative wind speeds (180° wind reversals) will not occur when the shears are associated with the wind profile envelope. To account for the effect of wind direction reversals, the 20 to 35 km altitude wind shears should be increased by 25 percent. The 99 percent level was chosen for the wind shears due to the lack of established relationships between wind shear and wind magnitude. Studies to establish these relationships are now underway.

3. Vertical Wind Speed Change Spectrums Associated with the 95 Percent Probability Wind Provile Envelope. The wind speed change spectrum shown in FIGURE 3 is the conversion of FIGURE 2 into wind speed change, corresponding to a change in altitude (scale-of-distance), and plotted as a function of altitude. Wind speed change is found by multiplying shear by scale-of-distance.

4. Selected Cross Sections of Vertical Wind Shear and Wind Speed Change. FIGURE 4 shows vertical wind shear versus scale-of-distance, taken from FIGURE 2, for altitude layers where vertical shear values are independent of altitude. These curves converted to wind speed change versus scale-of-distance are shown in FIGURE 5. They represent the envelope of the wind buildup rate to the wind magnitude envelope given in FIGURE 1. Similar buildup curves to be associated with the wind speed profile envelope may be constructed for any altitude.

5. Ninety-Nine Percent Probability Wind Profile Envelope and Associated Vertical Wind Shears. The 99 percent probability wind profile envelope given in FIGURE 6 was derived in the same manner as the 95 percent wind profile envelope given in FIGURE 1 and is interpreted in the same way. That is, wind speeds will be exceeded only one percent of the time in the 10 to 14 km altitude region during the windiest month of the year. The bar graph in FIGURE 6 is analogous to the one in FIGURE 1. It shows the percent of time that the 97 m/sec wind speed is exceeded in the 10 to 14 km altitude region.

Vertical wind shear and wind speed change spectrums, as presented in FIGURES 2, 3, 4, and 5 for the 95 percent probability level wind profile envelope, should also be used with the 99 percent probability wind profile envelope. For the higher wind speeds, associated with the probability-of-occurrence levels above approximately 95 percent, studies have not shown any great differences in terms of wind shear and wind speed relationships. Whether the wind speed is near the 95 percent or 99 percent probability-of-occurrence level or not, there is about the same probability that a given wind shear versus scale-of-distance will not be exceeded. Therefore, until more extensive and detailed data become available and are analyzed, the shears described in FIGURES 2, 3, 4, and 5 should be employed with the 95 and 99 percent wind profile envelopes (FIG. 1 and 6) to establish wind buildup rates for synthetic wind profile construction. Detail studies are presently in progress regarding the relationship between wind speed and wind shear over the larger scale of distance ($\geq$ 1000 m) for which sufficient data are available.

6. Synthetic Wind Profile Construction. FIGURE 7 illustrates the philosophy employed to construct synthetic profiles from the previcusly described data. (The 95 percent probability wind profile envelope is used in this illustration; however, the same technique applies to the 99 percent profile.) The wind speed change data associated with the various scale-of-distances as a function of altitude, which are given on the wind speed change spectrum graph in FIGURE 3, are employed to determine the synthetic wind profile to be associated with a given altitude. The result is a wind buildup to the wind speed given by the wind profile envelope graph at the selected altitude. This technique produces an envelope about the wind shear or wind speed change values and results in a synthetic wind profile leading to a wind speed specifically applicable to a given

altitude level. The synthetic wind profile is constructable over a maximum altitude layer of 5000 m below a given altitude level. For purposes of continuity, an extension of the profile may be made by using a minimum profile slope to zero wind speed at the surface. These profiles provide for an envelope of wind shear conditions for study of system responses to the wind environment and, therefore, are rather conservative statistical estimates of the various wind shear interrelationships. A conservative approach is required where studies necessitate synthetic wind profile inputs until more descriptive statistical representations, based on detailed analytical and theoretical studies of the wind environment, are obtained.

Tabulated values for data given in FIGURES 1, 2, 3, and 6 are given in Tables I, II, III, and IV for easy reference and use in computer programs.

SECTION V. AVERAGE PERCENTAGE OF MONTHLY PERIODS THAT VARIOUS WIND MAGNITUDES ARE EXCEEDED IN 10 TO 14 KM ALTITUDE REGION, CAPE CANAVERAL, FLORIDA

There is some interest in restricting certain missile or space vehicle test launches, due to control or structrual design limitations, until winds are below a given value in the high dynamic pressure region (10 to 14 km altitude). A graph (FIG. 11) has been prepared to illustrate the effect on test schedules for Cape Canaveral, Florida. This graph provides information on the average (mean) percentage of the monthly periods that the various wind magnitudes (20 m/sec through 97 m/sec) are exceeded. As an example, if wind limitation for 60 m/sec in the high dynamic pressure region (10 to 14 km altitudes) is necessary on a given vehicle configuration, then during March there would be on an average 13 percent of the period, or 4 days, when the vehicle could not operate. For other monthly periods, it would be less. The summer months are, without exception, the best months for tests which might have critical wind magnitude limitations.

It should be noted that these are average values for the percentage of monthly periods which exceed a given wind magnitude and are based on about 9 years of records for Cape Canaveral. However, for any given year, there may exist periods when the winds will exceed the given magnitudes for a period considerably more than the average. This is referred to as persistence. One persistence case, for exceeding the 75 m/sec level, went for 8 days in February, 1958, whereas the highest average for a monthly period is 1-1/2 days, based on all records. A separate and detailed study is being conducted regarding persistence for various wind magnitudes over Cape Canaveral, Florida. These data will be provided in a later publication.

The information in the graph (FIG. 11) should be very worthwhile in making judgements relative to effects of limiting vehicle tests based on the 10 to 14 km altitude wind magnitudes. Also, the graph illustrates rather clearly the dependence on season or monthly periods for the occurrence of high wind speeds. Therefore, by the use of such data, special missions may be planned and undertaken during periods when the risk for exceeding a given design wind magnitude is at a minimum.

SECTION VI. THE INTERRELATIONSHIPS OF COMPONENT SHEARS AND THEIR RELATION TO THE MISSILE OR SPACE VEHICLE PITCH AND YAW PLANES IN THE TROPOSPHERE AND LOWER STRATOSPHERE (10-14 KM ALTITUDE REGION)

A. THE RELATION BETWEEN VERTICAL, HORIZONTAL, AND PERPENDICULAR SHEAR COMPONENTS

As pointed out earlier in this report, an adequate statistical relationship does not exist between the wind shears for the various scale-of-distances; neither does one exist between the various shear components (horizontal, vertical, and perpendicular wind shears). The wind shears for the various scale-of-distances or between the wind shear components is primarily due to the lack of adequate data. Until better theoretical or statistical models can be developed, showing these relationships, it must be assumed for structural and control system studies that wind shears for the given scale-of-distances are combined to produce over-all wind build-up rates which will impose the most stringent design conditions on the vehicle. This suggests the highly improbable condition that a perfect correlation exists between the various wind shears defined by the probability-of-occurrence envelope established previously. This assumption affords a conservative approach in establishing design and control requirements, and will be assumed here. A review of Section II should be made due to the dependence of the following discussion on the definitions given for the various parameters.

The magnitudes of vertical shears over various distances have been determined with a reasonable degree of accuracy in the troposphere and lower stratosphere from balloon and missile measurements (angle-of-attack) of wind. However, horizontal and perpendicular components of shear have not been measured accurately and, therefore, must be approximated. The estimated magnitudes of the envelope of vertical, horizontal, and perpendicular shear components in the 10 to 14 km altitude region to scale-of-distances are shown in FIGURE 8 (values are tentative for illustrative purposes only).

Detailed descriptions of the horizontal wind velocity field (over distances of 5 km and less) have not been determined except near the ground. However, estimates of the horizontal component of wind shear over short horizontal distances (< approximately 100 m) can be made from the statistical properties of turbulence, and over larger horizontal distances (> approximately 10 km) from aircraft and balloon measurements. Over distances of approximately a hundred meters and less, atmospheric turbulence is thought to be nearly isotropic. Therefore, the magnitude of wind shear is independent of direction. Thus, over these distances the magnitudes of vertical and horizontal shears are, for all practical purposes, equal. Over larger distances the magnitude of wind shear in the vertical direction, $\frac{\partial W}{\partial y}$, becomes progressively larger than the shear in a horizontal direction, $\frac{\partial W}{\partial s}$. Measurements made by aircraft near the jet stream (10 to 14 km altitude region) indicate that only under extreme conditions the horizontal wind speed may change as much as 20 m/sec in a horizontal distance of 15 km (Ref. 12).

The envelope of horizontal shear given in FIGURE 8 was established in the following manner:

It was assumed that turbulence is isotropic for distances less than 100 meters. At this point and for smaller distances, the magnitudes of the horizontal and vertical shear components are equal. On the other extreme, the envelope of horizontal shear, at a distance of 5000 meters, was established by extrapolation of the measured values given in Reference 12. The envelope between these points represents the best estimate of what is expected to occur over these scale-of-distances. This estimate is substantiated in part by the apparent existence of eddies which have a greater horizontal than vertical dimension. Although only partially supported by detail measurements (Ref 19), this theory has been advanced by several outstanding investigators of upper air turbulence.

The envelope for the perpendicular shear component, $\frac{\partial V}{\partial s}$, is highly speculative since direct measurements are not available for analysis. In practice, the usual procedure is to determine the average vertical component of the wind speed over large geographical areas using basic equations of meteorology. The average magnitude of this component, excluding violent weather phenomena such as thunderstorms, tornadoes, and hurricanes, is only a few centimeters per second. However, values of 30 to 50 m/sec are not uncommon in the more severe thunderstroms.

The perpendicular shear component envelope was established by assuming a constant difference in the vertical wind velocity components (ΔV) of 9 m/sec for all scale-of-distances. This is a conservative estimate for the envelope of perpendicular shears, excluding violent weather phenomenon such as thunderstorms and hurricanes.

For convenience in computations, it is desirable to establish the relationships between the probability-of-occurrence envelopes for horizontal and perpendicular shears in terms of the probability-of-occurrence envelope for vertical shear. FIGURE 9 shows the relative magnitudes of the component shears as the percent of horizontal and perpendicular shears to vertical shears. The magnitudes of horizontal and perpendicular shears are almost equal for the various scale-of-distances and are considerably lower than the vertical shears. This is due to the assumption of eddies having a greater horizontal than vertical and lateral dimensions.

FIGURE 10 illustrates the wind speed change for the vertical, horizontal, and perpendicular wind shears as a function of scale-of-distance. This is a conversion of the data given in FIGURE 8 for easy reference in terms of wind speed change. The assumption of a limiting vertical wind velocity ($\triangle V$) of 9 m/sec is illustrated by a straight line in the graph. By using these data or referring to FIGURE 9, it is possible to describe the total shear acting normal to a vehicle axis as a function of the vertical shear only, and at the same time maintain a compatible relationship between the component shears. These relationships may be considered valid only in the 10 to 14 km altitude region.

B. THE RELATION BETWEEN COMPONENT SHEARS AND THE VEHICLE PITCH AND YAW PLANES.

For structural and control studies, it is necessary to determine the effect of each of the component shears with regard to the pitch and yaw planes. To review, the pitch plane is defined by the vertical axis (earth-fixed coordinates) and the longitudinal axis of the vehicle; the yaw plane is at right angles to the pitch and xy-planes, and goes through the longitudinal axis of the vehicle (FIG. 12).

In the following discussion of the shear components and their relations to the pitch and yaw planes, it will be assumed that the x-axis is oriented in the plane of the direction of flight in an earth-fixed coordinate system. The vehicle is not pitching or yawing (the orientation of the x-axis is irrelevant to this discussion, but will be assumed to coincide with the direction of flight for clarity). In this case, the longitudinal axis of the vehicle coincides with the tangent to the trajectory (θ) so that $\phi_p = \theta_p$, and since the trajectory lies in the xy-plane, $\Phi_y = \theta_y = 0$. It will be further assumed that the vehicle travels in a straight line over the relatively short distances considered here. (FIGURE 12.)

1. <u>Vertical Shear</u>. From the above assumptions, the distance a vehicle travels along the direction of flight, $\triangle r$, corresponding to an altitude, $\triangle y$, is $\triangle r = \frac{\triangle y}{\cos \Phi_p}$. The part of the vertical shear vector, $\left(\frac{\triangle W}{\triangle r}\right)_v$, which the vehicle will experience in traveling a distance along the direction of flight, $\triangle r$, is:

$$\left(\frac{\Delta W}{\Delta r}\right)_v = \frac{\Delta W}{\frac{\Delta y}{\cos \Phi_p}} = \frac{\Delta W}{\Delta y} \cos \Phi_p . \tag{1}$$

When $\Phi_p = 0$ (vehicle rising vertically), Δr will equal Δy and the vehicle will experience the vertical shears of the magnitudes given in FIGURE 2. Another limiting condition is when $\Phi_p = 90°$ (vehicle flying horizontally), in which case, the vertical shear is zero. Therefore, for a given travel distance, Δr, the magnitude of the vertical shear which the vehicle experiences is determined by the attitude angle.

The question now arises: What part of the vertical shear vector is normal to the vehicle in the pitch and yaw planes for a given attitude, Φ_p? The vertical shear vector, $\frac{\Delta W}{\Delta y}$ or $\left(\frac{\Delta W}{\Delta r}\right)_v$, lies in a plane which is parallel to the xz-plane, and may have any direction in that plane. In practice, the orientation of the shear vector will not be known. In determining the part of the vertical shear vector that is normal to the vehicle axis in the pitch plane, the vector will be assumed to be in the pitch plane. With this orientation, the shear vector may be resolved into components which are normal and along the vehicle axis. The normal component, $\left(\frac{\Delta W}{\Delta r}\right)_v^P$, is given by:

$$\left(\frac{\Delta W}{\Delta r}\right)_v^P = \left(\frac{\Delta W}{\Delta r}\right)_v \cos \Phi_p \tag{2}$$

Substituting equation (1) into equation (2):

$$\left(\frac{\Delta W}{\Delta r}\right)_v^P = \frac{\Delta W}{\Delta y} \cos^2 \Phi_p \tag{3}$$

This equation shows that the percentage of the vertical shear vector that is normal to the vehicle axis in the pitch plane is proportional to $\cos^2\Phi_p$. A graph of this function is shown in FIGURE 13.

In determining the component of the vertical shear vector that is normal to the vehicle axis in the yaw plane, it will be assumed that the vector lies in the yaw plane. This assumption is valid, as pointed out above, since the vertical shear vector may have any direction in the plane of the vector. In this case, the total vertical shear vector may be normal to the vehicle axis in the yaw plane, i.e.,

$$\left(\frac{\Delta W}{\Delta r}\right)_v^Y = \left(\frac{\Delta W}{\Delta r}\right)_v \tag{4}$$

where $\left(\frac{\Delta W}{\Delta r}\right)_v$ is given by equation (1).

2. Horizontal Shear. By definition, horizontal shears are measured in a plane perpendicular to the plane in which vertical shears are measured and parallel to the plane tangent to the earth's surface. The horizontal shear vector is in the same plane as the vertical shear vector and may have the same direction. The distance a vehicle travels along the direction of flight, Δr, corresponding to the distance, Δs, in the plane where horizontal shears are measured is $\Delta r = \frac{\Delta s}{\sin \Phi_p}$. Therefore, the part of the horizontal shear vector, $\left(\frac{\Delta W}{\Delta r}\right)_h$, which the vehicle will experience in traveling a distance along the direction of flight, Δr, is:

$$\left(\frac{\Delta W}{\Delta r}\right)_h = \frac{\frac{\Delta W}{\Delta s}}{\sin \Phi_p} = \frac{\Delta W}{\Delta s} \sin \Phi_p \qquad (5)$$

This equation shows that for $\Phi_p = 0$ (vehicle rising vertically), the horizontal shears affecting the vehicle will be zero, and for $\Phi_p = 90°$ (horizontal flight), the horizontal shears affecting the vehicle will be those given in FIGURE 8, or $\left(\frac{\Delta W}{\Delta r}\right)_h = \frac{\Delta W}{\Delta s}$. Assuming that the horizontal shear vector lies in the pitch plane, it can be resolved into components which are normal to and along the vehicle axis. The normal components, $\left(\frac{\Delta W}{\Delta r}\right)_h^P$, is given by:

$$\left(\frac{\Delta W}{\Delta r}\right)_h^P = \left(\frac{\Delta W}{\Delta r}\right)_h \cos \Phi_p \qquad (6)$$

Subsitituting equation (5) into equation (6):

$$\left(\frac{\Delta W}{\Delta r}\right)_h^P = \frac{\Delta W}{\Delta s} \sin \Phi_p \cos \Phi_p \qquad (7)$$

This equation shows that the percentage of horizontal shear that is normal to the vehicle axis in the pitch plane is proportional to $\sin \Phi_p \cos \Phi_p$. A graph of this function is given in FIGURE 14.

In determining the component of the horizontal shear vector that is normal to the vehicle axis in the yaw plane, the same assumption will be made that was made for the vertical shear vector (viz), the horizontal shear vector lies in the yaw plane. As in the case of vertical shear, the total horizontal shear vector may be normal to the vehicle axis in the yaw plane, i.e.,

$$\left(\frac{\Delta W}{\Delta r}\right)_h^Y = \left(\frac{\Delta W}{\Delta r}\right)_h \tag{8}$$

where $\left(\frac{\Delta W}{\Delta r}\right)_h$ is given by equation 5.

3. Perpendicular Shear. Perpendicular shear is defined as the change in the vertical wind component along an axis in the xz-plane. Thus, the perpendicular shear vector is always parallel to the y-axis (perpendicular). The distance the vehicle travels along the direction of flight, Δr, corresponding to the distance, Δs, in the plane where perpendicular shears are measured is $\Delta r = \frac{\Delta s}{\sin \Phi_p}$. The component of the perpendicular shear vector which the vehicle will experience in the pitch plane is given by:

$$\left(\frac{\Delta V}{\Delta r}\right)_p = \frac{\Delta V}{\frac{\Delta s}{\sin \Phi_p}} = \frac{\Delta V}{\Delta s} \sin \Phi_p \tag{9}$$

This shear vector will always lie in the pitch plane since it is always parallel to the y-axis. When resolved into components normal to and along the vehicle axis, the component of the perpendicular shear vector normal to the vehicle axis is given by:

$$\left(\frac{\Delta V}{\Delta r}\right)_p = \left(\frac{\Delta V}{\Delta r}\right)_p \sin \Phi_p \tag{10}$$

Substituting equation (9) into equation (10):

$$\left(\frac{\Delta V}{\Delta r}\right)_p^P = \frac{\Delta V}{\Delta s} \sin^2 \Phi_p \tag{11}$$

This equation shows that the percentage of the perpendicular shear vector that is normal to the vehicle axis in the pitch plane is proportional to $\sin^2 \Phi_p$. A graph of this function is given in FIGURE 15.

Because of the restriction placed on the direction of the perpendicular shear vector (it is always parallel to the y-axis), it is not possible for a component of this vector to be normal to the vehicle axis in the yaw plane.

C. THE COMBINED EFFECT OF COMPONENT SHEARS IN THE PITCH AND YAW PLANES

The vertical wind shear vector and the horizontal wind shear vector both lie in a plane parallel to the xz-plane that intersects the y-axis at some point away from the origin. These vectors may be in either the pitch or yaw planes. If either of these vectors lie entirely in either plane, then the vector will not have a component normal to the vehicle in the other plane. In practice, the orientation of these vectors is not known and the possibility that both vectors have a component normal to the vehicle axis in either plane must be considered. Therefore, assuming that these vectors and the perpendicular shear vector all have a component normal to the vehicle axis, the maximum possible shears, for the probability-of-occurrence level under consideration, acting normal to the vehicle in the pitch plane, S_P, is given by the vector sum of equations 3, 7, and 11, (viz):

$$S_P = \left(\frac{\Delta W}{\Delta r}\right)_v^P + \left(\frac{\Delta W}{\Delta r}\right)_h^P + \left(\frac{\Delta V}{\Delta r}\right)_p^P \qquad (12)$$

Similarly, the maximum possible shear acting normal to the vehicle axis in the yaw plane, S_Y, is given by equations 4 and 8, (viz):

$$S_Y = \left(\frac{\Delta W}{\Delta r}\right)_v^Y + \left(\frac{\Delta W}{\Delta r}\right)_h^Y \qquad (13)$$

Substituting equations (3), (4), (7), (8), and (11) into equations (12) and (13):

$$S_P = \frac{\Delta W}{\Delta y} \cos^2\varphi_p + \frac{\Delta W}{\Delta s} \sin\varphi_p \cos\varphi_p + \frac{\Delta V}{\Delta s} \sin^2 \varphi_p \qquad (14)$$

and,

$$S_Y = \frac{\Delta W}{\Delta y} \cos\varphi_p + \frac{\Delta W}{\Delta s} \sin\varphi_p \qquad (15)$$

The first step to be performed in evaluating equations (14) and (15) is to determine horizontal and/or perpendicular scale-of-distance, Δs, corresponding to a given value of the attitude angle, φ_p, and the vertical scale-of-distance, Δy. For a given vertical scale-of-distance, Δy, vertical shears may be determined from FIGURE 2. Horizontal and perpendicular shears, $\frac{\Delta W}{\Delta s}$ and $\frac{\Delta V}{\Delta s}$, respectively, may be obtained from FIGURE 8. These values are then substituted into equations (14) and (15). For example, suppose it is desired to determine the maximum possible shear normal to the vehicle axis in the pitch plane, S_p, over a flight path distance of 2000 meters (Δr) when the attitude angle (φ_p) is 15°. (It should be kept in mind that the discussion here applies only in the 10-14 km altitude region.) Vertical shear, $\frac{\Delta W}{\Delta y}$, for Δy = 1931 m (2000 cos 15°) in the 10-14 km altitude region is 0.024 sec^{-1}. This value was taken from FIGURE 2. The horizontal travel distance of the vehicle, Δs, corresponding to a flight path distance (Δr) of 2000 m is 517 m (2000 sin 15°). Horizontal shear corresponding to this scale-of-distance may be obtained from FIGURE 8. The magnitude of horizontal shear is 0.019 sec^{-1} (Δs = 517 meters). The magnitude of perpendicular shear is determined in a similar manner and the values of the three shear components are substituted into equation (14) to obtain the maximum possible shear normal to the vehicle axis in the pitch plane, which may act over a flight path distance of 2000 m for a $\varphi_p = 15°$.

FIGURES 16 and 17 show the magnitude of S_P and S_Y in the 10 to 14 km altitude region for attitude angles of 0, 15, 45, and 90 degrees and for various flight path distances. As the attitude angle approaches zero, the shears in the pitch and yaw planes approach the magnitude of the vertical shear. As the attitude angle increases, the contribution made by the vertical shear component, which is the largest of all components, contributes less to the total shear and becomes zero for horizontal flight (attitude angle = 90°).

The basic purpose of the material presented in this section is to describe the interrelationship between various wind shears relative to a vehicle not in vertical flight. This problem has been raised with regard to various control studies. The idea is to illustrate the application of the concept outlined in this section regarding relationship between component shears and the vehicle axis. The numerical values employed are tentative and considerable study and investigation will be necessary to establish statistically significant values and relationship for the component shears.

SECTION VII. COMMENTS

The basic philosophy underlying synthetic profiles for use in missile design and performance studies is that certain wind speeds and wind shear values will not be exceeded more than a certain percent of the time. This means that a vehicle system must be designed to withstand a combination of near maximum wind speeds and associated shears. This philosophy has at least two major shortcomings (viz), (1) maximum wind speeds are assumed to occur simultaneously with maximum wind shears for all scale-of-distances, and (2) the spatial distribution of wind maxima (peaks along the wind speed profile which a vertically rising vehicle sees as repeated gusts), which may cause the vehicle system to oscillate, is not specified. Even so, with the present state of the art in measuring detailed atmospheric motions and the available analytical techniques for employing more complex statistical representations of available data in design studies, the data presented herein are considered the most reliable wind criteria for use in missile and space vehicle design studies presently available for Cape Canaveral (Atlantic Missile Range), Florida.

For purposes of some MSFC space vehicle design studies, the 95 percent probability-of-occurrence wind profile envelope and associated wind shears or wind buildup spectrums are utilized. This is the present design philosophy for the Saturn C-1 vehicles and involves the acceptance of a possible 5 percent loss in launch time for the windiest monthly period. In the event that mission schedules are to be stringent in terms of permissible launch times and the acceptance of a delay of one to two days, on the average for the windiest monthly period, may seriously interfere with the utilization of a given space vehicle, the higher probability (99%) wind profile should be used for design of the structural and control system. This will then provide a launch capability with a minimum loss in launch time due to delays for occurrences of wind conditions above the design limits of the structural and control system. However, due to the added structural and control system capability which must be accommodated in the system design with increase of design philosophy from 95 percent to 99 percent operational capability, the various trade-offs in terms of performance, payload capability, mission requirements, etc., must be considered.

The envelopes of wind speed and the spectrums of wind shear and wind speed change presented in this report are independent of wind direction. Therefore, for the purpose of structural and control system design, these values should be applied for all directions with regard to the vehicle axis. In some cases, it may be desirable to employ envelopes of wind components relative to a given flight azimuth. For example, the envelope of wind magnitudes for head, tail, and crossrange components may be lower than the scalar speed envelope. The use of these profiles may, therefore, reduce the control or design requirements for systems that are more sensitive to one wind component that to another. Envelopes of headwind, tailwind, right-crosswind, and left-crosswind components for various probability levels and firing directions for Cape Canaveral are given in references 15, 16 and 17. Also, the distribution of the North, South, East, and West components are given in reference 18 for various probability levels.

NOTE: The material presented in this report was previously published for limited distribution as MTP-AERO-61-48, "Description of Wind Shears Relative to a Missile/Space Vehicle Axis and a Presentation of the Cape Canaveral, Florida, 95 and 99 Percent Probability Level Standardized Wind Profile Envelopes (1-80 km) and Associated Wind Shears for Use in Design and Performance Studies," June 8, 1961.

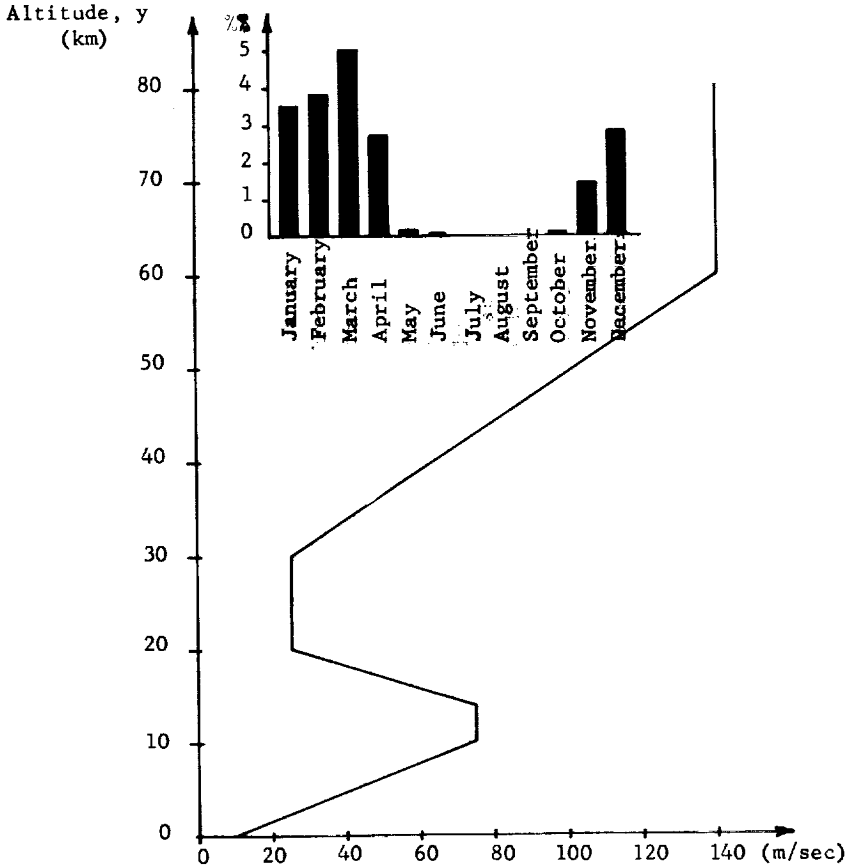


FIGURE 1. NINETY-FIVE PERCENT PROBABILITY-OF-OCCURRENCE WITH SPEED PROFILE ENVELOPE FOR CAPE CANAVERAL, FLORIDA, AND THE AVERAGE PERCENTAGE OF MONTHLY PERIOD THAT THE 75 M/SEC WIND SPEED IS EXCEEDED IN THE 10-14 KM ALTITUDE REGION

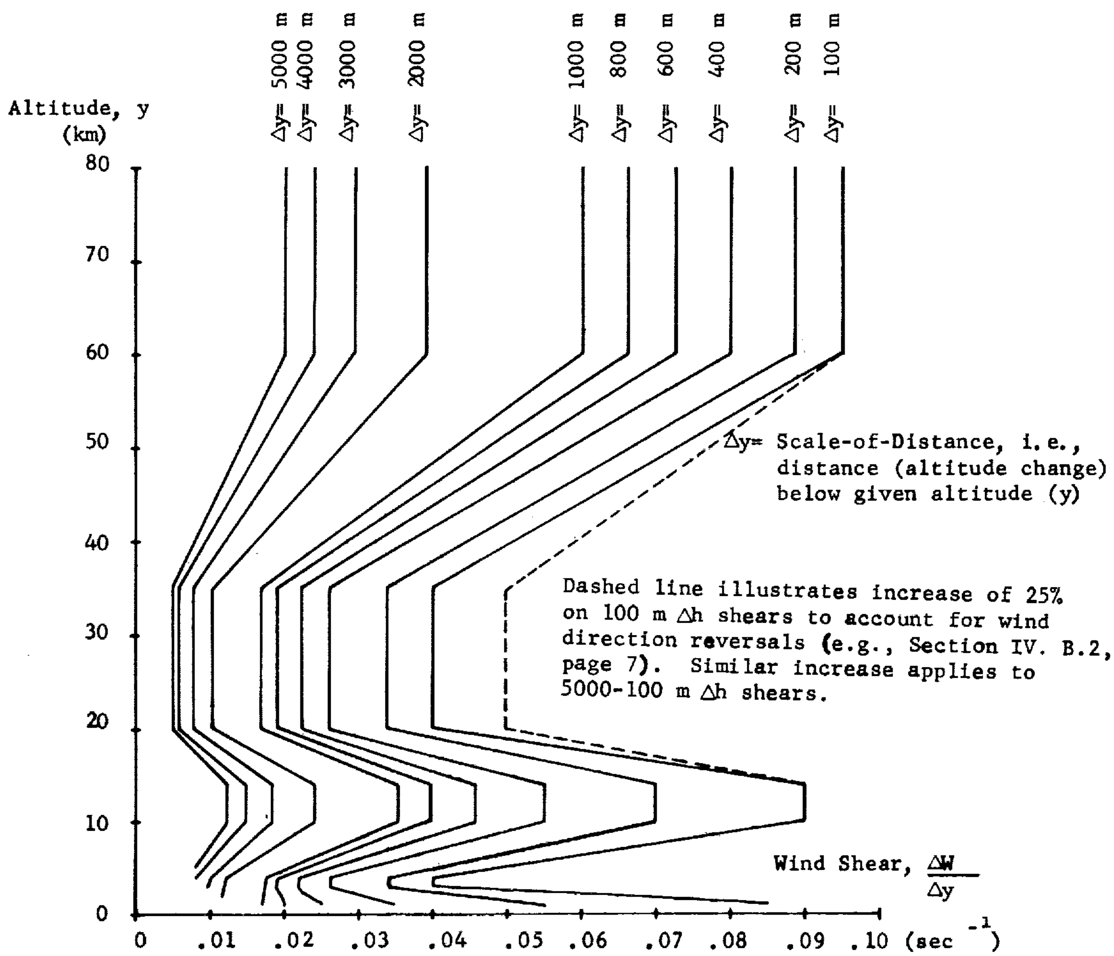


FIGURE 2. NINETY-NINE PERCENT PROBABILITY-OF-OCCURRENCE VERTICAL WIND SHEAR SPECTRUM AS FUNCTION OF ALTITUDE AND SCALE-OF-DISTANCE FOR ASSOCIATION WITH THE NINETY-FIVE AND NINETY-NINE PERCENT WIND SPEED PROFILE ENVELOPE FOR CAPE CANAVERAL, FLORIDA

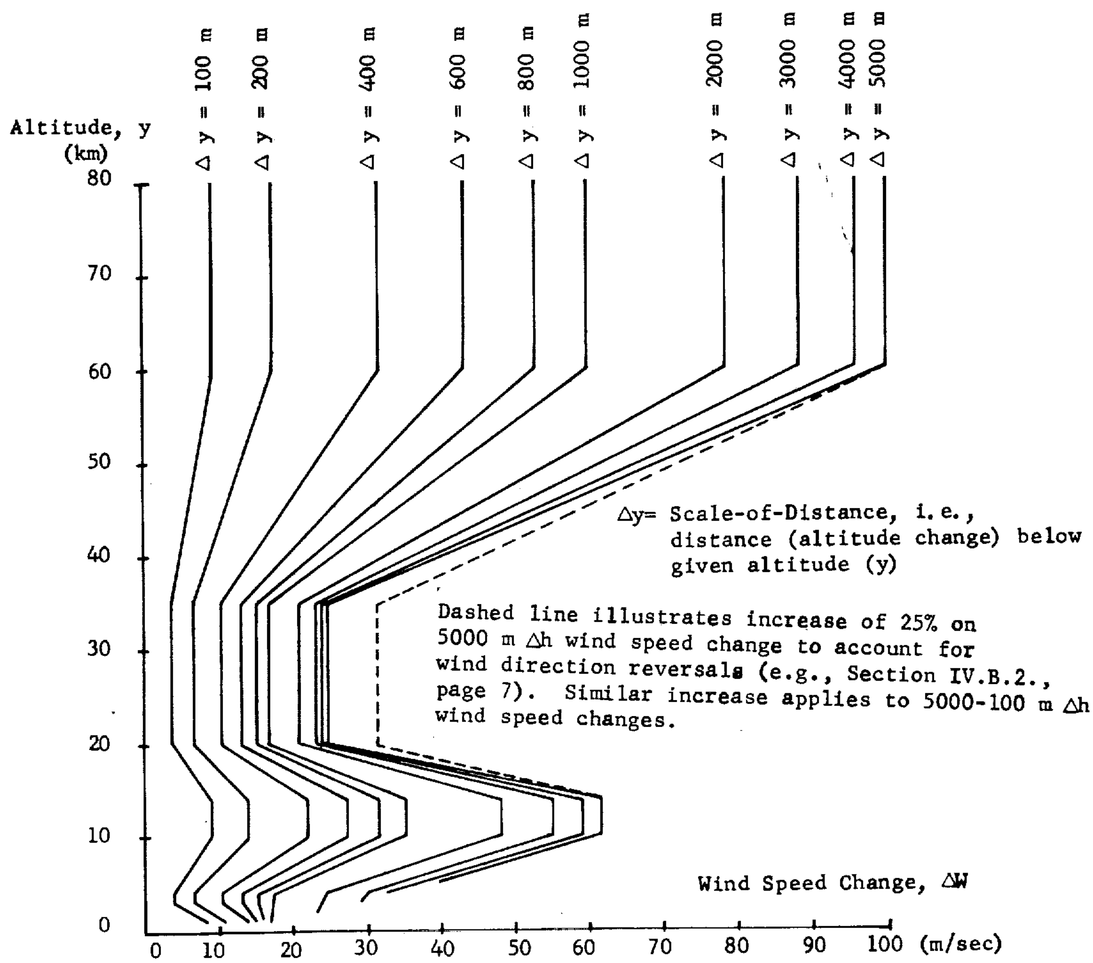


FIGURE 3. NINETY-NINE PERCENT PROBABILITY-OF-OCCURRENCE VERTICAL WIND SPEED CHANGE SPECTRUM AS FUNCTION OF ALTITUDE AND SCALE-OF-DISTANCE ASSOCIATED WITH THE NINETY-FIVE AND NINETY-NINE PERCENT WIND SPEED PROFILE ENVELOPE

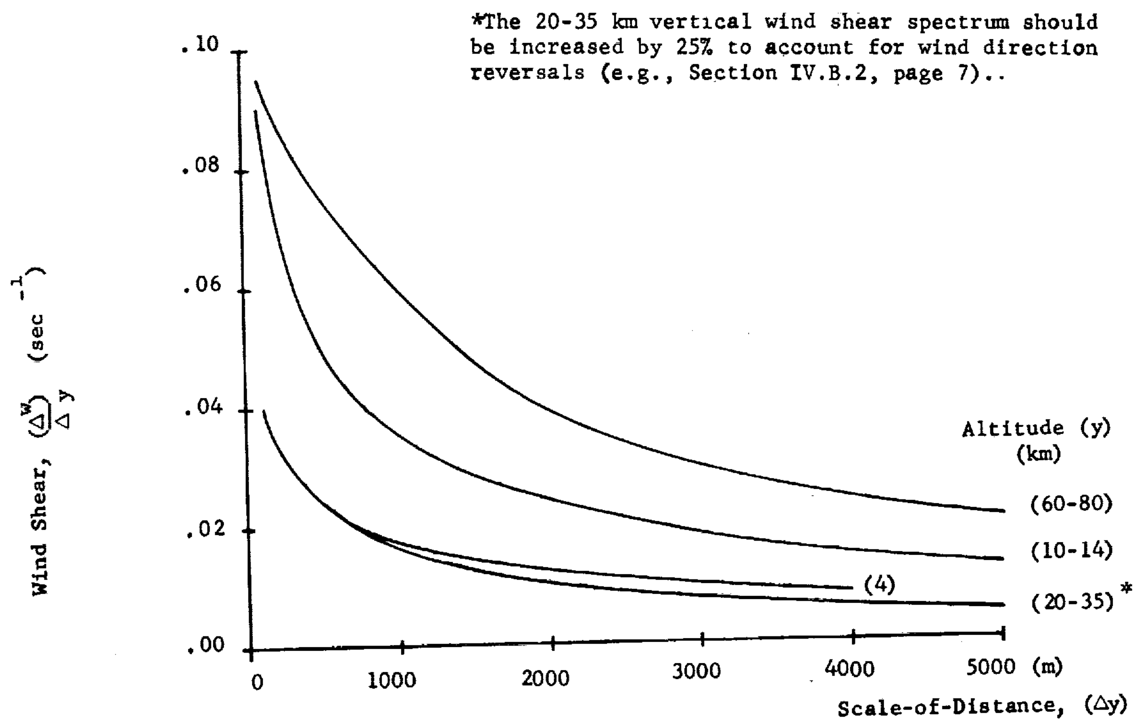


FIGURE 4. SELECTED VERTICAL WIND SHEAR SPECTRUMS (4 KM, 10-14 KM, 20-35 KM, AND 60-80 KM ALTITUDE) FOR USE WITH NINETY-FIVE AND NINETY-NINE PERCENT PROBABILITY LEVEL WIND PROFILE ENVELOPE, CAPE CANAVERAL, FLORIDA

*The 20-35 km vertical wind speed change spectrum should be increased by 25% to account for wind direction reversals (e.g., Section IV.B.2, page 7).

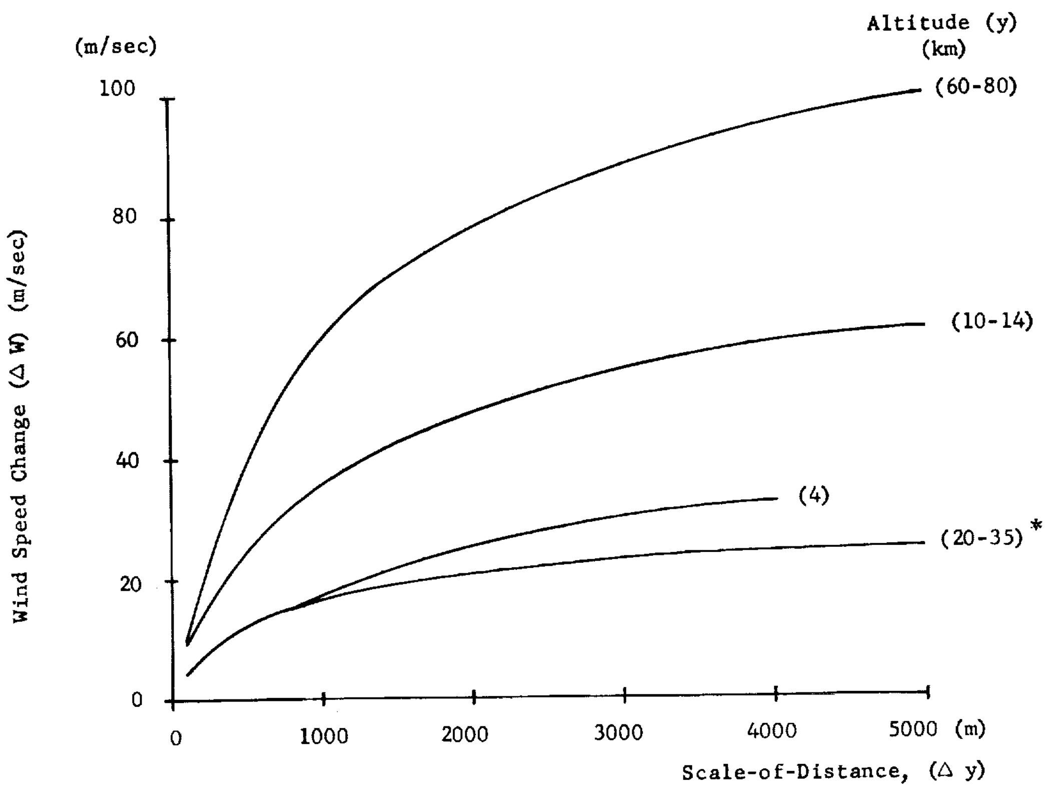


FIGURE 5. SELECTED VERTICAL WIND SPEED CHANGE SPECTRUMS (4KM, 10-14 KM, 20-35 KM, AND 60-80 KM ALTITUDE) FOR USE WITH NINETY-FIVE AND NINETY-NINE PERCENT PROBABILITY LEVEL WIND PROFILE ENVELOPE, CAPE CANAVERAL, FLORIDA

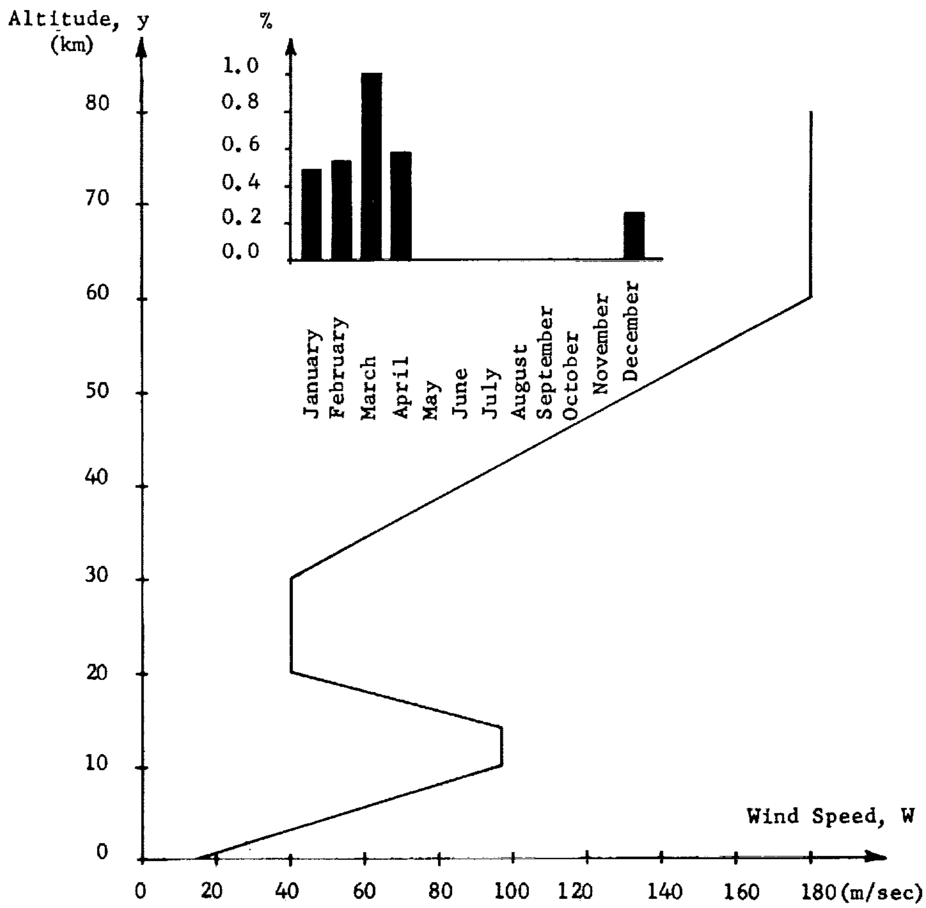


FIGURE 6. NINETY-NINE PERCENT PROBABILITY-OF-OCCURRENCE WIND SPEED PROFILE ENVELOPE FOR CAPE CANAVERAL, FLORIDA, AND THE AVERAGE PERCENTAGE OF MONTHLY PERIOD THAT THE 97 M/SEC WIND SPEED IS EXCEEDED IN THE 10-14 KM ALTITUDE REGION.

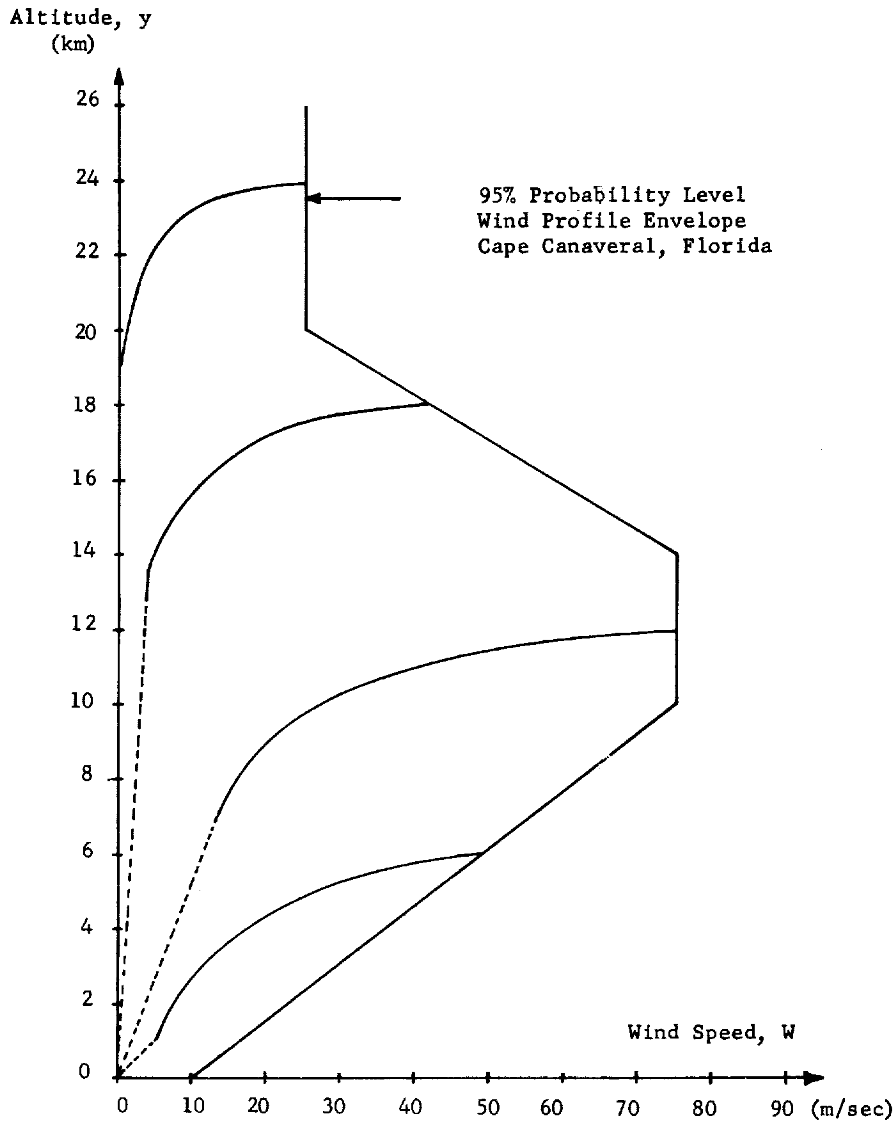


FIGURE 7. EXAMPLES OF SYNTHETIC WIND PROFILES BASED ON NINETY-NINE PERCENT WIND BUILD-UP RATES TO BE ASSOCIATED WITH THE NINETY-FIVE PERCENT PROBABILITY WIND SPEED PROFILE ENVELOPE AT 6, 12, 18, AND 24 KM ALTITUDES

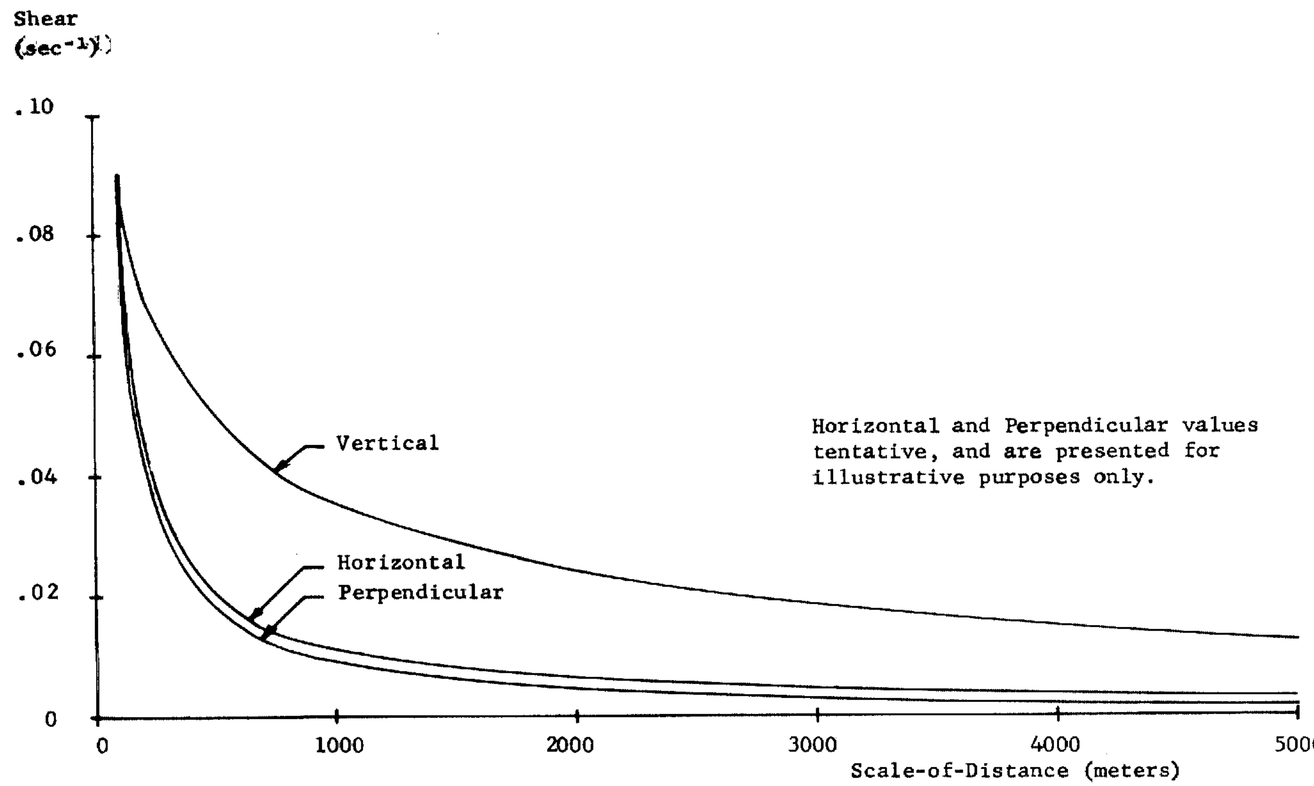


FIGURE 8. ENVELOPES OF THE MAGNITUDE OF WIND SHEAR AS A FUNCTION OF SCALE-OF-DISTANCE FOR VERTICAL, HORIZONTAL, AND PERPENDICULAR SHEAR COMPONENTS IN THE 10-14 KM ALTITUDE REGION

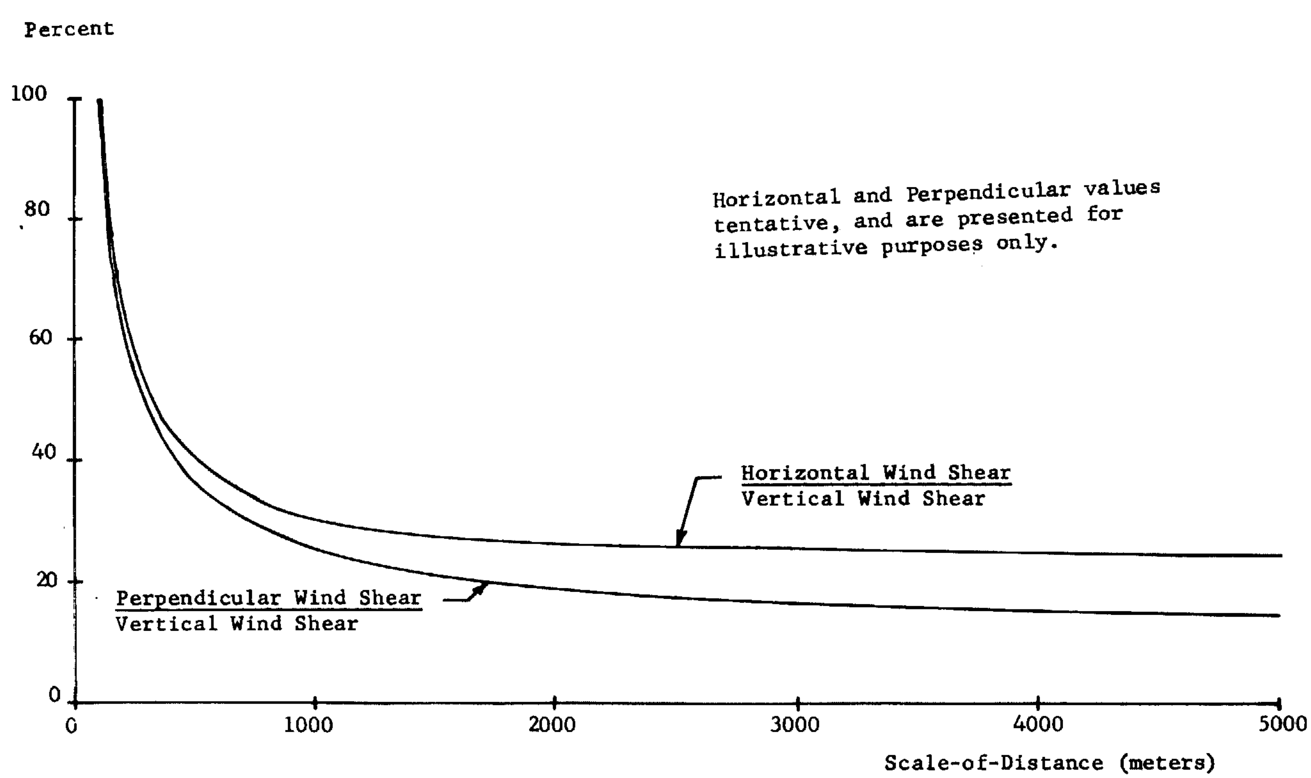


FIGURE 9. ENVELOPES OF HORIZONTAL AND PERPENDICULAR WIND SHEARS AS A FUNCTION OF ENVELOPE OF VERTICAL WIND SHEARS IN THE 10-14 KM ALTITUDE REGION

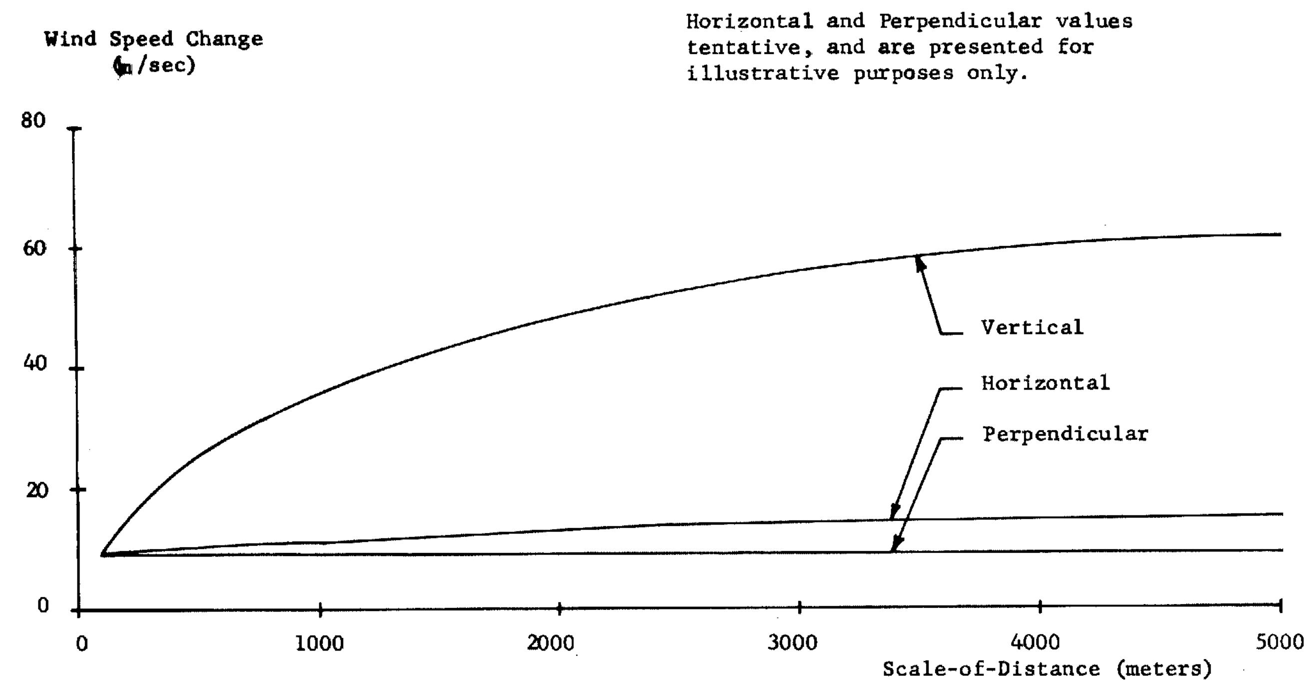


FIGURE 10. ENVELOPES OF THE HORIZONTAL, PERPENDICULAR, AND VERTICAL WIND SPEED CHANGE SPECTRUMS FOR THE 10-14 KM ALTITUDE REGION

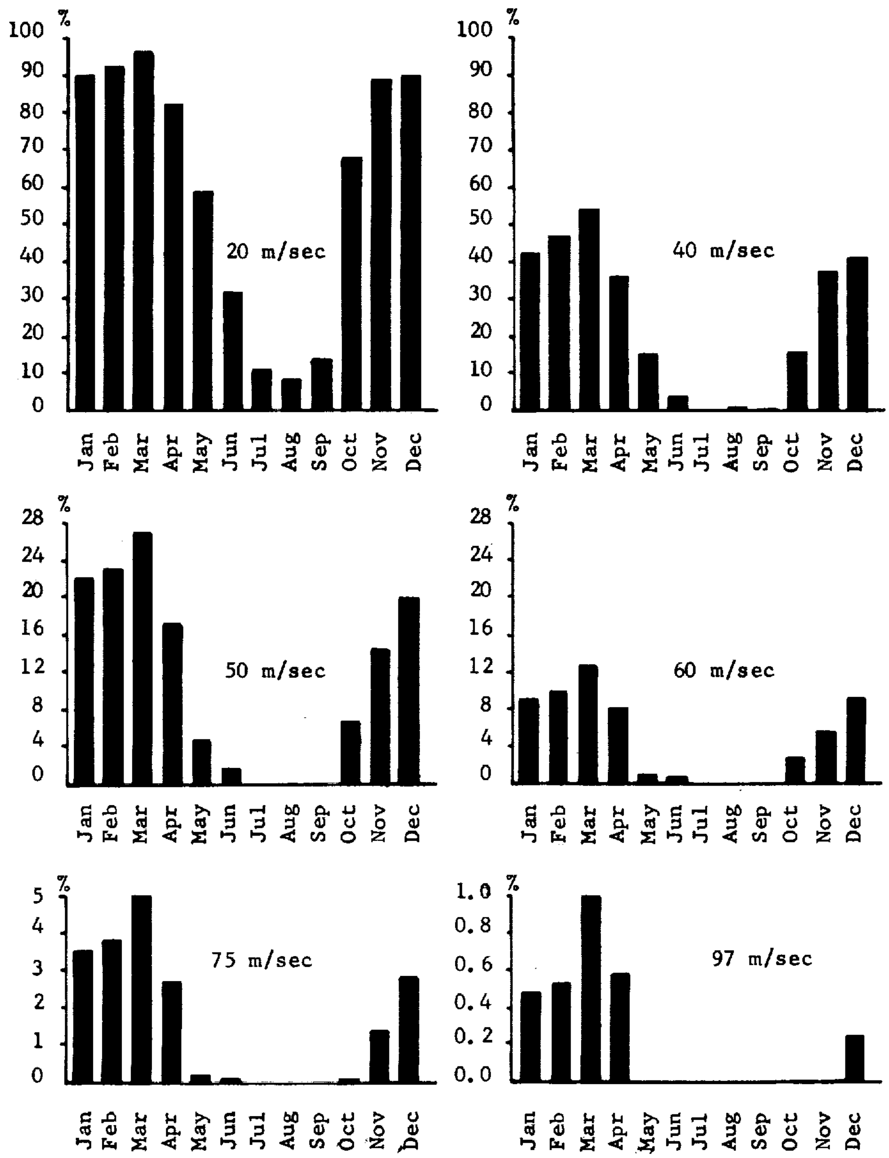


FIGURE 11. AVERAGE (MEAN) PERCENTAGE OF MONTHLY PERIODS THAT THE 20, 40, 50, 60, 75, & 97 M/SEC WIND SPEEDS ARE EXCEEDED IN THE 10-14 KM ALTITUDE REGION CAPE CANAVERAL, FLORIDA

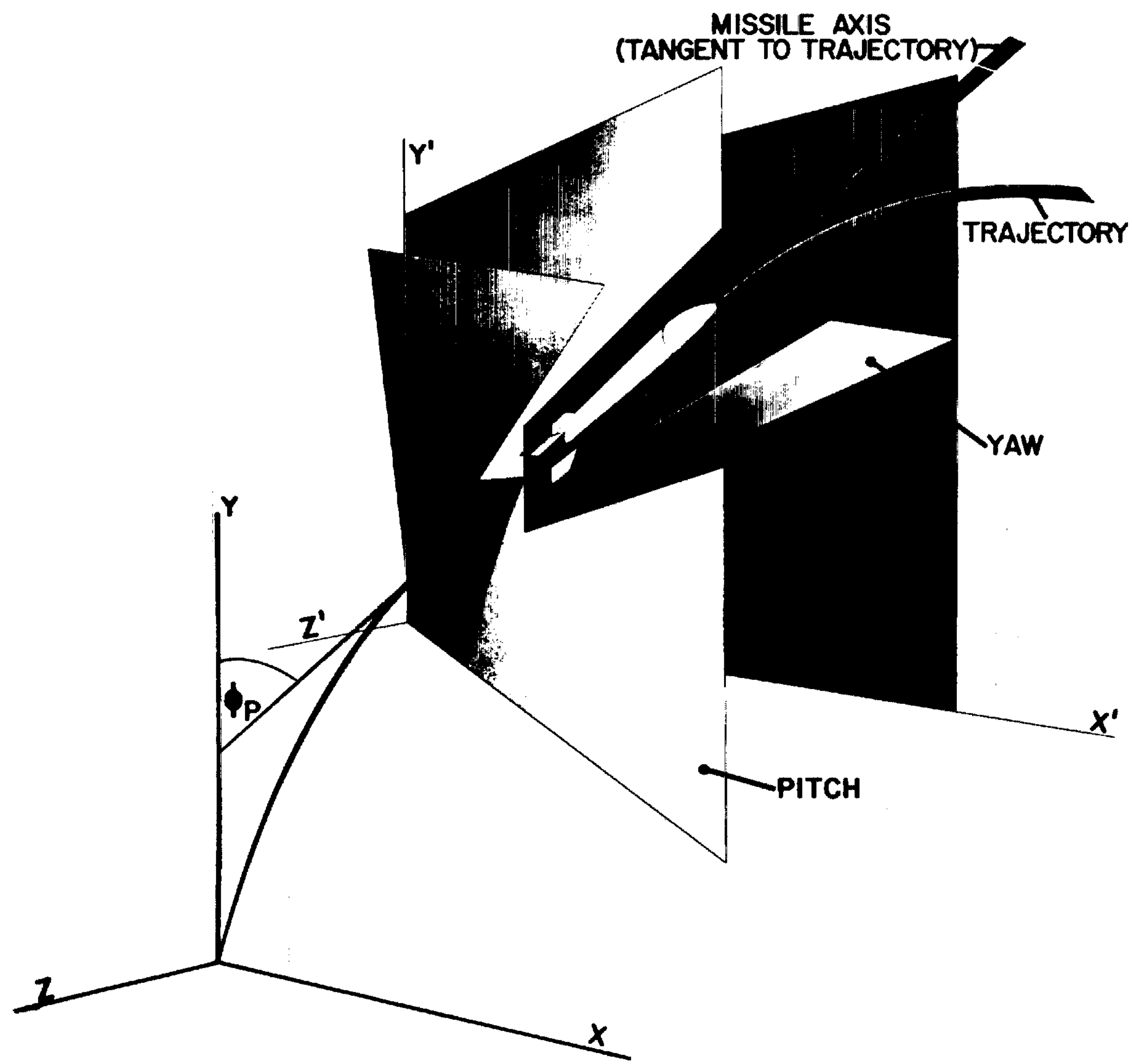


FIGURE 12. THE PITCH AND YAW PLANES IN RELATION TO THE COORDINATE AXIS AND A VEHICLE INCLINED FROM THE VERTICAL AT AN ANGLE ϕ_P

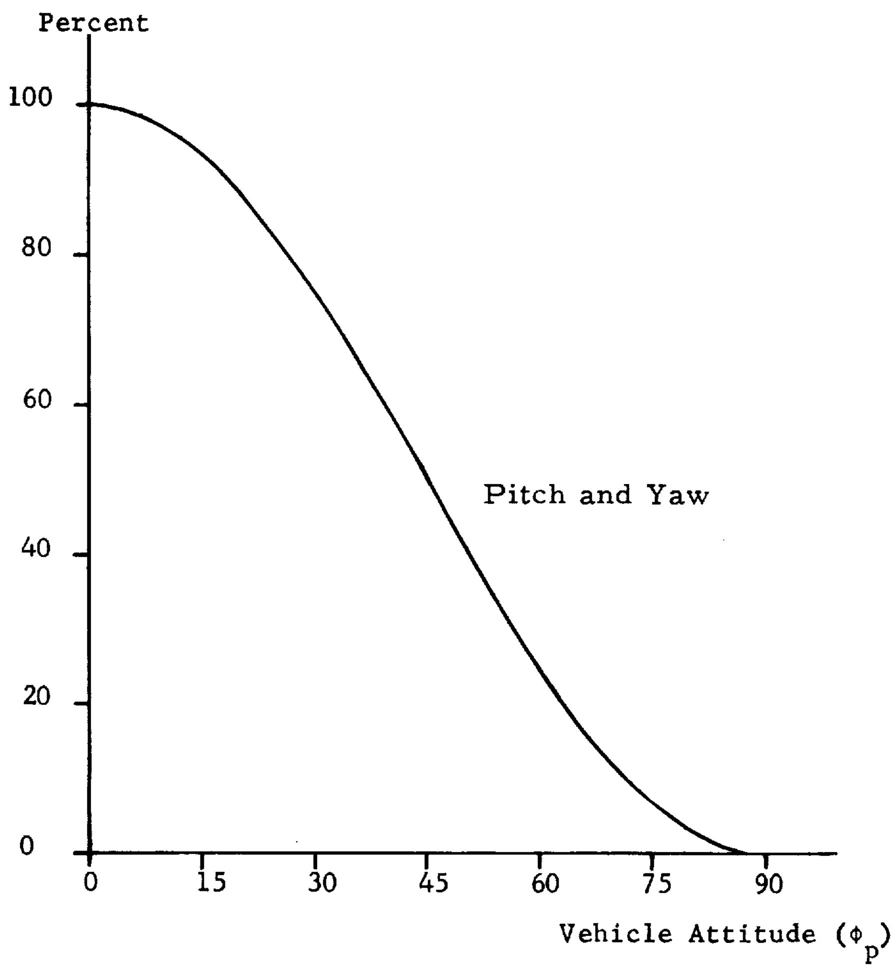


FIGURE 13. PERCENT OF THE VERTICAL SHEAR VECTOR NORMAL TO THE VEHICLE AXIS AS A FUNCTION OF THE VEHICLE'S ATTITUDE

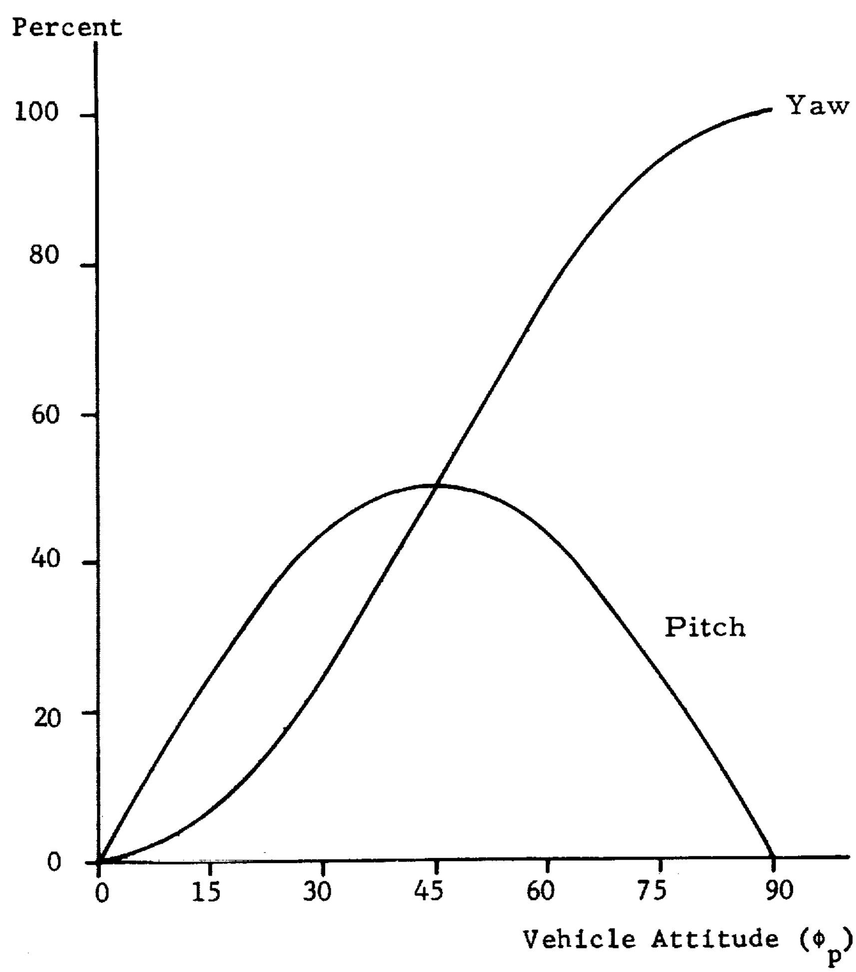


FIGURE 14 PERCENT OF THE HORIZONTAL SHEAR VECTOR NORMAL TO THE VEHICLE AXIS AS A FUNCTION OF THE VEHICLE'S ATTITUDE

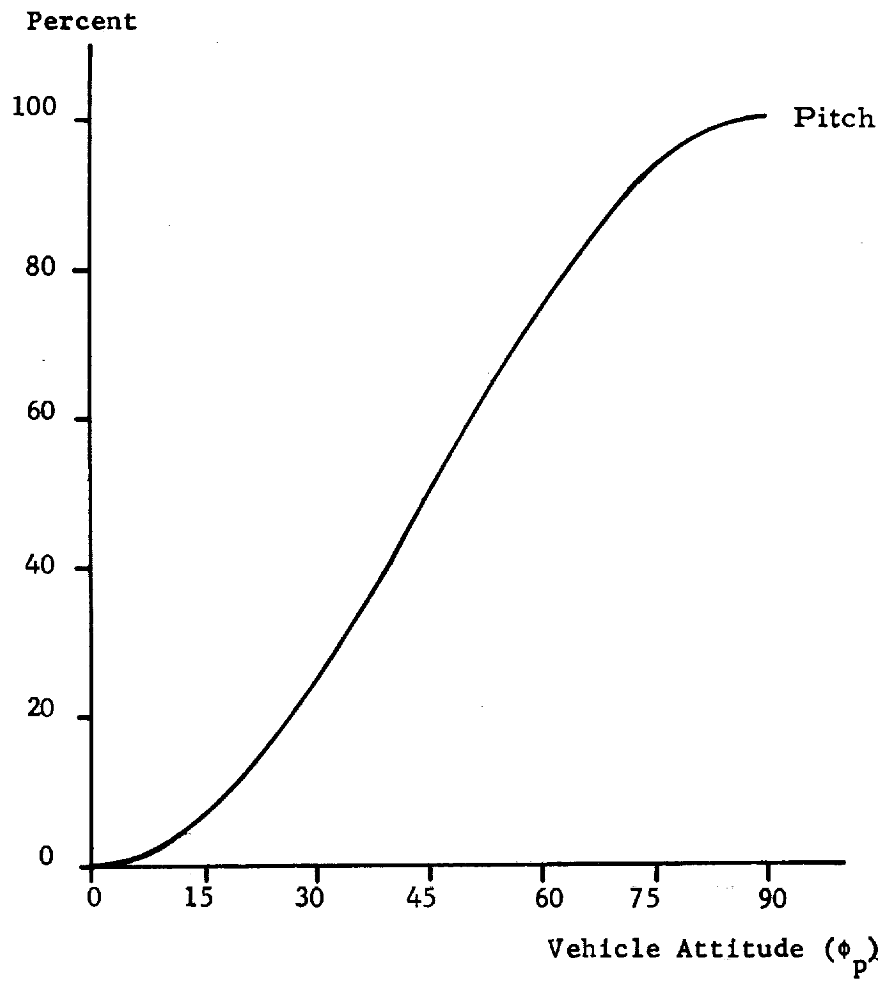


FIGURE 15. PERCENT OF THE PERPENDICULAR SHEAR VECTOR NORMAL TO THE VEHICLE AXIS AS A FUNCTION OF THE VEHICLE'S ATTITUDE

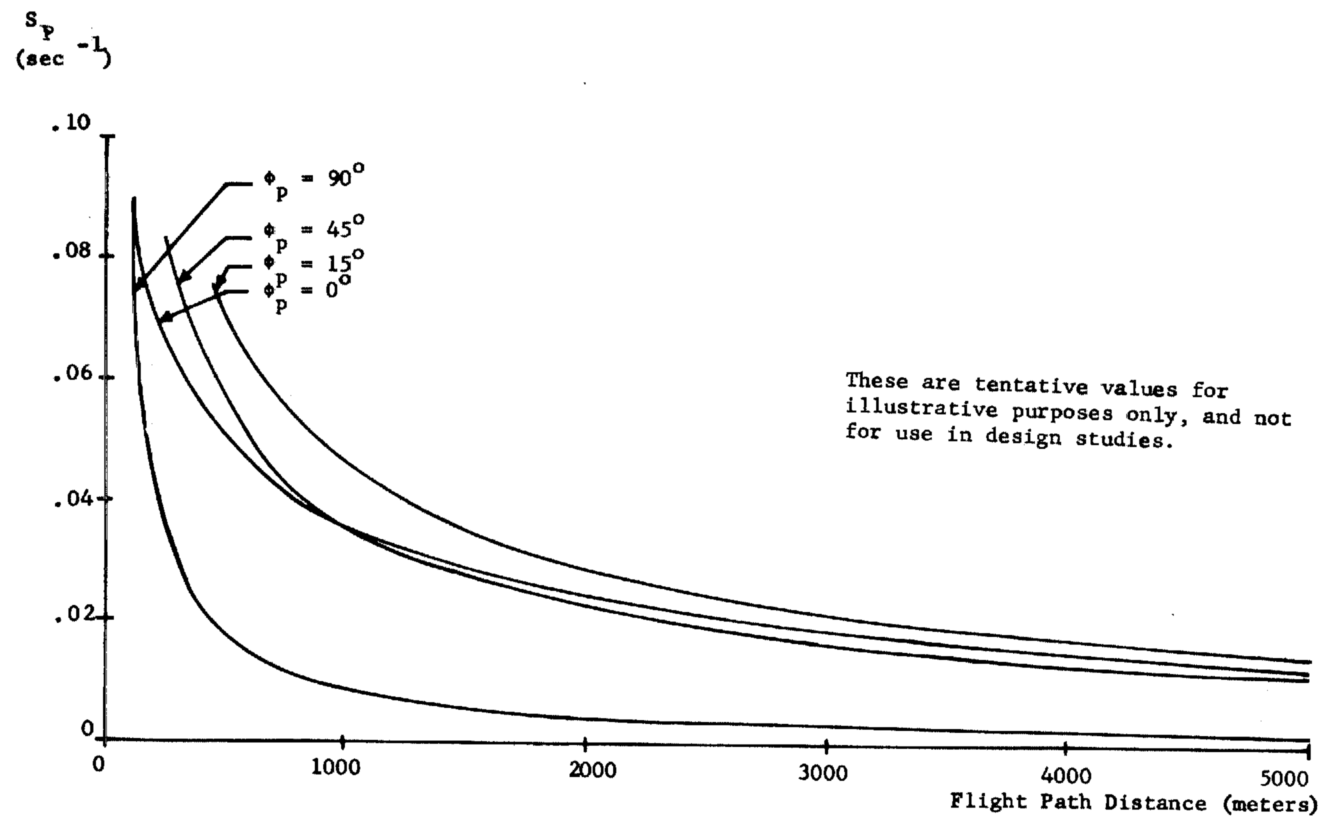


FIGURE 16. THE MAXIMUM POSSIBLE SHEAR NORMAL TO VEHICLE AXIS IN PITCH PLANE, S_P, AS FUNCTION OF VEHICLE FLIGHT PATH DISTANCE AND FOR ATTITUDE ANGLES OF 0, 15, 45, AND 90 DEGREES

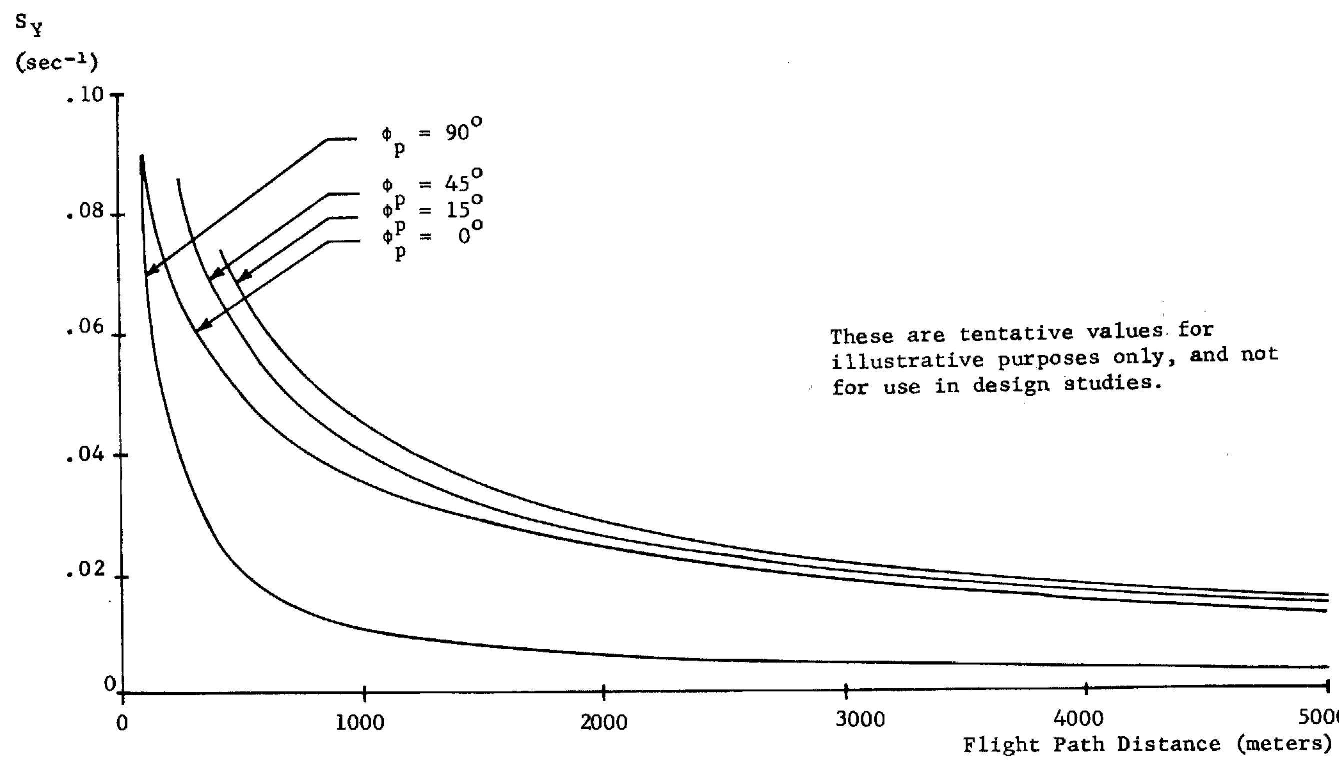


FIGURE 17. THE MAXIMUM POSSIBLE SHEAR NORMAL TO VEHICLE AXIS IN YAW PLANE, S_Y, AS FUNCTION OF VEHICLE FLIGHT PATH DISTANCE AND FOR ATTITUDE ANGLES OF 0, 15, 45, AND 90 DEGREES

TABLE I

IDEALIZED NINETY-FIVE PERCENT PROBABILITY-OF-OCCURRENCE WIND PROFILE ENVELOPE

Alt (km)	Wind Speed (m/sec)
surface	10
10	75
14	75
20	25
30	25
60	140
80	140

TABLE II

IDEALIZED NINETY-NINE PERCENT PROBABILITY-OF-OCCURRENCE WIND PROFILE ENVELOPE

Alt (km)	Wind Speed (m/sec)
surface	15
10	97
14	97
20	40
30	40
60	180
80	180

Table III

NINETY-NINE PERCENT PROBABILITY-OF-OCCURRENCE WIND SHEAR (SEC^{-1}) SPECTRUM ASSOCIATED WITH THE NINETY-FIVE AND NINETY-NINE PERCENT WIND PROFILE ENVELOPE

Alt	(Scale-of-Distance (m))									
(km)	5000	4000	3000	2000	1000	800	600	400	200	100
1	--	--	--	--	.0170	.0200	.0253	.0350	.0550	.0850
2	--	--	--	.0116	--	--	--	--	--	--
3	--	--	.0097	--	--	.0190	.0222	.0263	.0340	.0400
4	--	.0081	.0100	.0122	.0175	.0190	.0222	.0263	.0340	.0400
5	.0079	--	--	--	--	--	--	--	--	--
10	.0123	.0148	.0184	.0240	.0353	.0396	.0457	.0550	.0700	.0900
14	.0123	.0148	.0184	.0240	.0353	.0396	.0457	.0550	.0700	.0900
*20	.0050	.0060	.0078	.0105	.0170	.0191	.0222	.0263	.0340	.0400
*35	.0050	.0060	.0078	.0105	.0170	.0191	.0222	.0263	.0340	.0400
60	.0200	.0240	.0295	.0393	.0600	.0662	.0727	.0800	.0885	.0950
80	.0200	.0240	.0295	.0393	.0600	.0662	.0727	.0800	.0885	.0950

*Shear values should be increased by 25% to account for wind direction reversals (e.g., Section IV.B.2, page 7).

Table IV

NINETY-NINE PERCENT PROBABILITY-OF-OCCURRENCE WIND SPEED CHANGE (M/SEC) SPECTRUM ASSOCIATED WITH THE NINETY-FIVE AND NINETY-NINE PERCENT WIND PROFILE ENVELOPE

Alt	(Scale-of-Distance(m))									
(km)	5000	4000	3000	2000	1000	800	600	400	200	100
1	--	--	--	--	17.0	16.0	15.2	14.0	11.0	8.5
2	--	--	--	23.2	--	--	--	--	--	--
3	--	--	29.1	--	--	15.2	13.3	10.5	6.8	4.0
4	--	32.4	30.0	24.4	17.5	15.2	13.3	10.5	6.8	4.0
5	39.5	--	--	--	--	--	--	--	--	--
10	61.5	59.2	55.2	48.0	35.3	31.7	27.4	22.0	14.0	9.0
14	61.5	59.2	55.2	48.0	35.3	31.7	27.4	22.0	14.0	9.0
*20	25.0	24.0	23.4	21.0	17.0	15.3	13.3	10.5	6.8	4.0
*35	25.0	24.0	23.4	21.0	17.0	15.3	13.3	10.5	6.8	4.0
60	100.0	96.0	88.5	78.6	60.0	53.0	43.6	32.0	17.7	9.5
80	100.0	96.0	88.5	78.6	60.0	53.0	43.6	32.0	17.7	9.5

*Wind speed change values should be increased by 25% to account for wind direction reversals (e.g., Section IV.B.2, page 7).

REFERENCES

1. Sissenwine, Norman, "Wind Speed Profile, Wind Shear, and Gusts for Design of Guidance Systems for Vertical Rising Air Vehicles," Air Force Surveys in Geophysics, No. 57, Air Research and Development Command, November 1954.

2. Dvoskin, Norman, and Sissenwine, Norman,"Evaluation of AN/GMD-2 Wind Shear Data for Development of Missile Design Criteria," Air Force Surveys in Geophysics, No. 99, Air Research and Development Command, April 1958.

3. Sissenwine, Norman, "Development of Missile Design Wind Profiles for Patrick AFB," Air Force Surveys in Geophysics, No. 96, Air Research and Development Command, March 1958.

4. Press, H., and Steiner, R.,"An Approach to the Problem of Estimating Severe and Repeated Gust Loads for Missile Operations," NACA TN 4332, September 1958.

5. Hobbs, Norman P. and others, "Development of Interim Wind, Wind Shear, and Gust Design Criteria for Vertically-Rising Vehicles," WADC Technical Report 59-504, July 1959.

6. Bieber, R. E., "Missile Structural Loads by Nonstationary Statistical Methods," Lockheed Aircraft Corporation, Sunnyvale, California, April 1959.

7. Ziejdel, Edmond F. E., and Blackburn, Robert R.,"Research and Development Services on the Loading of Missiles Due to Atmospheric Turbulence and Wind Shear," Final Report, Project No. 2315-P, Midwest Research Institute, Kansas City, Missouri, June 1960.

8. Zeijdel, Edmond F. E., and Blackburn,Robert R., "Research on Loading of Missiles Due to Atmospheric Turbulence and Wind Shear," Progress Report No. 6, 1 April-30 April 1961, Project No. 2455-P, Midwest Research Institute, Kansas City, Missouri.

9. Vaughan, William W., "Interlevel and Intralevel Correlations of Wind Components for Six Geographical Locations," NASA TN D-561, December, 1960.

10. Smith, Orvel E., "A Reference Atmosphere for Patrick AFB, Florida (Annual)," NASA TN-D-595, July 1960.

REFERENCES (Cont'd)

11. Minzner, R. A., and others, "The ARDC Model Atmosphere, 1959, "Air Force Surveys in Geophysics, No. 115, Air Research and Development Command, August 1959.

12. "Handbook of Geophysics," Revised Edition, U. S. Air Force, Air Research and Development Command, The MacMillian Co., New York, 1960.

13. Vaughan, William W., "Analysis of Discrete Atmospheric Gust Velocity Data for Use in Missile Design and Performance Studies," ABMA DA-TR-68-59, 20 November 1959.

14. Vaughan, William W., "Investigation of the Cape Canaveral, Florida Wind Magnitude and Wind Shear Characteristics in the Ten to Fourteen Kilometer Altitude Region," NASA Technical Note D-556, January 1961.

15. Vaughan, W. W., "Empirical Three-Sigma Wind Component Profiles 45-Degree Missile Flight Azimuth, Atlantic Missile Range, Patrick AFB (Cape Canaveral), Florida," 1961, NASA Technical Note D-606.

16. Vaughan, W. W., "Empirical Three-Sigma Wind Component Profiles, 105-Degree Missile Flight Azimuth, Atlantic Missile Range, Patrick AFB (Cape Canaveral), Florida," 1959, ABMA DA-TR-67-59.

17. Vaughan, W. W., "Empirical Three-Sigma Wind Component Profiles 67 1/2-Degree Missile Flight Azimuth, Atlantic Missile Range, Patrick AFB (Cape Canaveral), Florida, 1960, ABMA DA-TR-16-60.

18. Smith, J. W., and Vaughan, W. W.,"Monthly and Annual Wind Distribution as a Function of Altitude for Patrick Air Force Base, Cape Canaveral, Florida," NASA Technical Note D-610, July 1961.

19. Sawyer, J. S., "Quasi-Periodic Wind Variations With Height in the Lower Stratosphere," Quarterly Journal of Royal Meteorological Society, Vol. 87, No. 371, pp 24-33, 1961.

NASA-Langley, 1962

NASA TN D-1274
National Aeronautics and Space Administration.
CAPE CANAVERAL WIND AND SHEAR DATA (1 THRU 80 KM) FOR USE IN VEHICLE DESIGN AND PERFORMANCE STUDIES. James R. Scoggins and William W. Vaughan. July 1962. 40p. OTS price, $1.00. (NASA TECHNICAL NOTE D-1274)

This report provides a review of the concept of wind shear and provides information relative to the various types of shears and their relationship for describing the wind environment. The use of these shear descriptions is described in terms of the vehicle flight attitude by resolving the shears as defined in an earth-fixed coordinate system into a vehicle-fixed coordinate system. A preliminary estimate is given for the magnitudes of perpendicular and horizontal wind shears as functions of the established vertical wind shears. In addition, a consolidated presentation is given of standardized wind profile envelopes for the 95 percent and 99 percent probability levels, and

(over)

I. Scoggins, James R.
II. Vaughan, William W.
III. NASA TN D-1274

(Initial NASA distribution:
2, Aerodynamics, missiles and space vehicles;
21, Geophysics and geodesy;
22, Guidance and homing systems;
23, Launching facilities and operations;
50, Stability and control;
51, Stresses and loads;
52, Structures.)

NASA

NASA TN D-1274
National Aeronautics and Space Administration.
CAPE CANAVERAL WIND AND SHEAR DATA (1 THRU 80 KM) FOR USE IN VEHICLE DESIGN AND PERFORMANCE STUDIES. James R. Scoggins and William W. Vaughan. July 1962. 40p. OTS price, $1.00. (NASA TECHNICAL NOTE D-1274)

This report provides a review of the concept of wind shear and provides information relative to the various types of shears and their relationship for describing the wind environment. The use of these shear descriptions is described in terms of the vehicle flight attitude by resolving the shears as defined in an earth-fixed coordinate system into a vehicle-fixed coordinate system. A preliminary estimate is given for the magnitudes of perpendicular and horizontal wind shears as functions of the established vertical wind shears. In addition, a consolidated presentation is given of standardized wind profile envelopes for the 95 percent and 99 percent probability levels, and

(over)

I. Scoggins, James R.
II. Vaughan, William W.
III. NASA TN D-1274

(Initial NASA distribution:
2, Aerodynamics, missiles and space vehicles;
21, Geophysics and geodesy;
22, Guidance and homing systems;
23, Launching facilities and operations;
50, Stability and control;
51, Stresses and loads;
52, Structures.)

NASA

NASA TN D-1274
National Aeronautics and Space Administration.
CAPE CANAVERAL WIND AND SHEAR DATA (1 THRU 80 KM) FOR USE IN VEHICLE DESIGN AND PERFORMANCE STUDIES. James R. Scoggins and William W. Vaughan. July 1962. 40p. OTS price, $1.00. (NASA TECHNICAL NOTE D-1274)

This report provides a review of the concept of wind shear and provides information relative to the various types of shears and their relationship for describing the wind environment. The use of these shear descriptions is described in terms of the vehicle flight attitude by resolving the shears as defined in an earth-fixed coordinate system into a vehicle-fixed coordinate system. A preliminary estimate is given for the magnitudes of perpendicular and horizontal wind shears as functions of the established vertical wind shears. In addition, a consolidated presentation is given of standardized wind profile envelopes for the 95 percent and 99 percent probability levels, and

(over)

I. Scoggins, James R.
II. Vaughan, William W.
III. NASA TN D-1274

(Initial NASA distribution:
2, Aerodynamics, missiles and space vehicles;
21, Geophysics and geodesy;
22, Guidance and homing systems;
23, Launching facilities and operations;
50, Stability and control;
51, Stresses and loads;
52, Structures.)

NASA

NASA TN D-1274
National Aeronautics and Space Administration.
CAPE CANAVERAL WIND AND SHEAR DATA (1 THRU 80 KM) FOR USE IN VEHICLE DESIGN AND PERFORMANCE STUDIES. James R. Scoggins and William W. Vaughan. July 1962. 40p. OTS price, $1.00. (NASA TECHNICAL NOTE D-1274)

This report provides a review of the concept of wind shear and provides information relative to the various types of shears and their relationship for describing the wind environment. The use of these shear descriptions is described in terms of the vehicle flight attitude by resolving the shears as defined in an earth-fixed coordinate system into a vehicle-fixed coordinate system. A preliminary estimate is given for the magnitudes of perpendicular and horizontal wind shears as functions of the established vertical wind shears. In addition, a consolidated presentation is given of standardized wind profile envelopes for the 95 percent and 99 percent probability levels, and

(over)

I. Scoggins, James R.
II. Vaughan, William W.
III. NASA TN D-1274

(Initial NASA distribution:
2, Aerodynamics, missiles and space vehicles;
21, Geophysics and geodesy;
22, Guidance and homing systems;
23, Launching facilities and operations;
50, Stability and control;
51, Stresses and loads;
52, Structures.)

NASA

NASA TN D-1274

related 99 percent envelopes of vertical wind shear and wind speed change spectrums for use in constructing synthetic statistical wind buildup profiles for Cape Canaveral, Florida (Atlantic Missile Range).

NASA

NASA TN D-1274

related 99 percent envelopes of vertical wind shear and wind speed change spectrums for use in constructing synthetic statistical wind buildup profiles for Cape Canaveral, Florida (Atlantic Missile Range).

NASA

NASA TN D-1274

related 99 percent envelopes of vertical wind shear and wind speed change spectrums for use in constructing synthetic statistical wind buildup profiles for Cape Canaveral, Florida (Atlantic Missile Range).

NASA

NASA TN D-1274

related 99 percent envelopes of vertical wind shear and wind speed change spectrums for use in constructing synthetic statistical wind buildup profiles for Cape Canaveral, Florida (Atlantic Missile Range).

NASA